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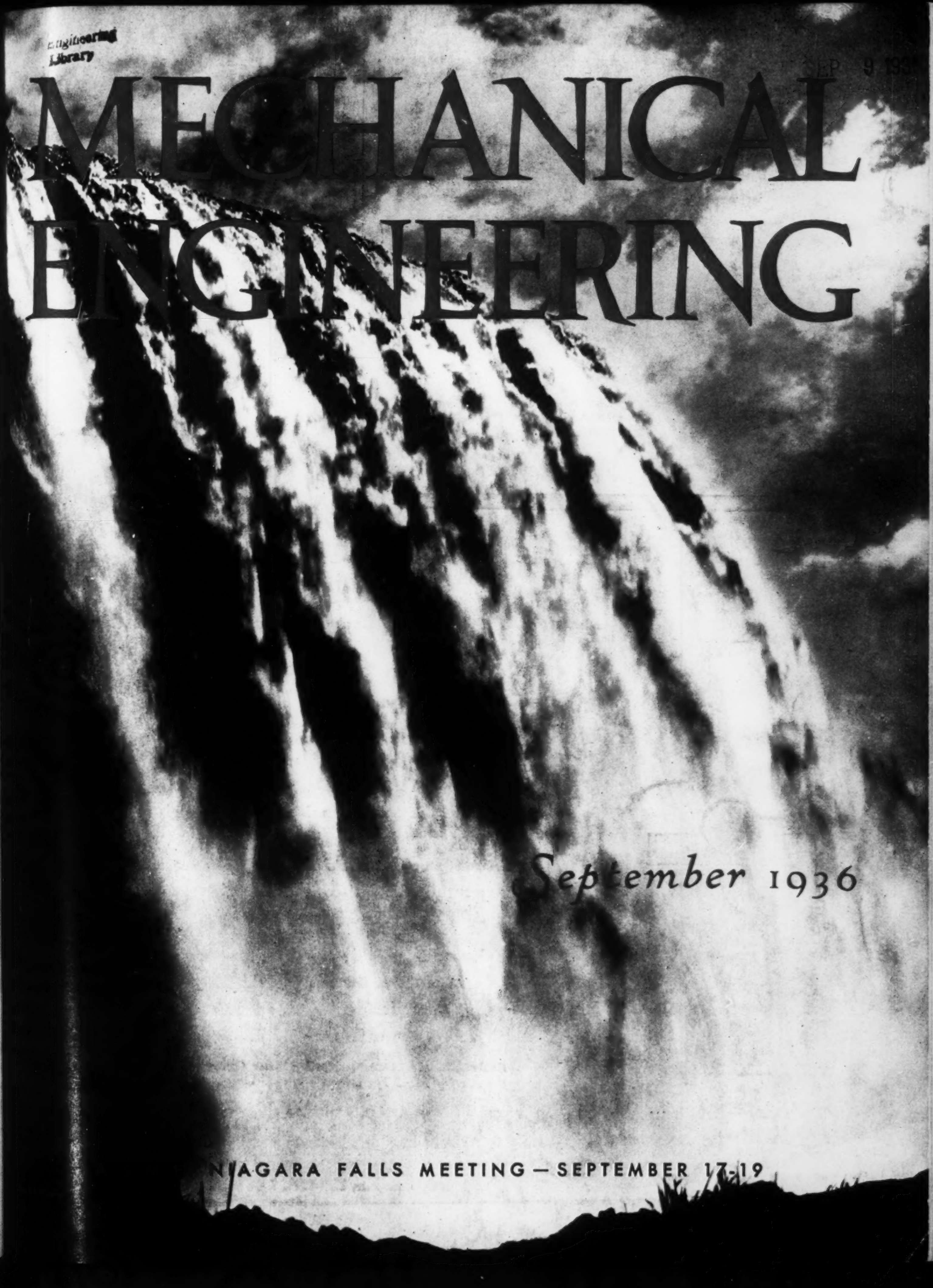
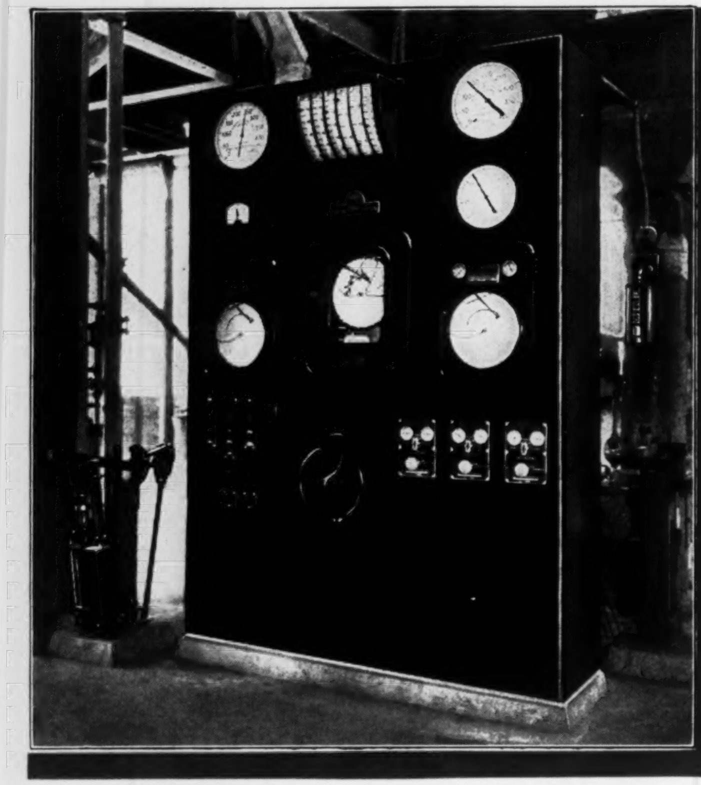


September 1936

NIAGARA FALLS MEETING — SEPTEMBER 17-19



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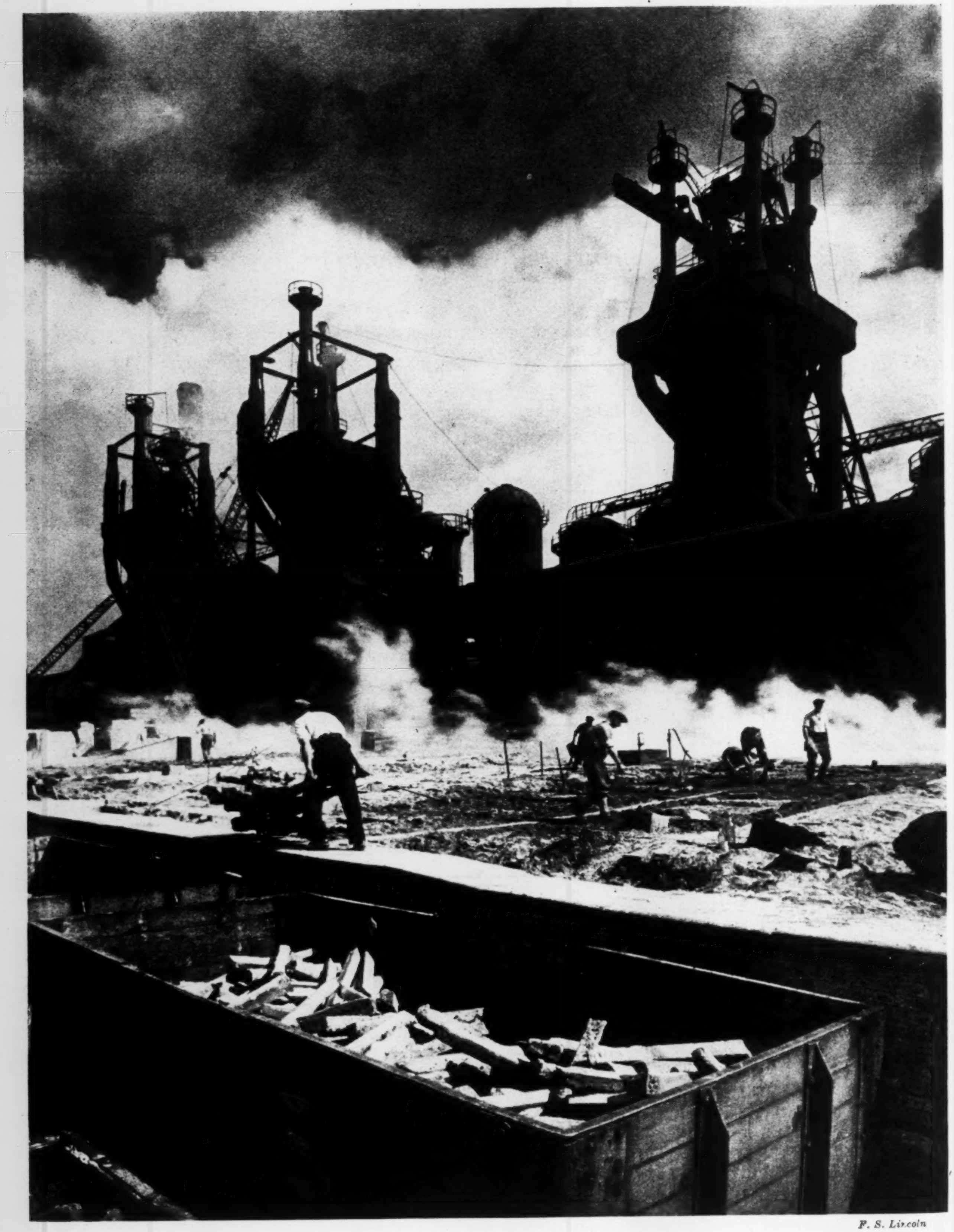

F. S. Lincoln

Corby Iron Works, Corby, England

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MECHANICAL ENGINEERING

SEPTEMBER
1936

GEORGE A. STETSON, *Editor*

Niagara Falls

IN ANTICIPATION of the meeting, September 17 to 19, of The American Society of Mechanical Engineers, it is profitable to refresh our minds on the significance of Niagara Falls to engineering and industry. Known the world over as one of Nature's greatest marvels, it has become also a symbol of man's achievement and an example of the best flowering of the American principle of free enterprise. The lessons it teaches are numerous and of enduring value. It will be well for us to heed them, for long after changes in technology and political institutions may have assigned other values to the development of this natural resource, men will continue to regard Niagara Falls as marking a great epoch in human progress.

Few projects in America have so long a history; with few engineering projects have such great names been associated. From the time when Chabert Joincaire, Jr., first utilized a six-foot fall in a loop canal in 1757 to the present the challenge of harnessing an enormous "free" power has engaged men's skill. Every advance has reflected progress in technology and has called for courage and faith. The very difficulties of the problem of effective utilization seem to have called forth the human energies necessary to surmount them.

A varied financial, industrial, and engineering history preceded the formation of the Cataract Construction Company in 1889, beginning with the developments of the Porter brothers in 1806 and culminating in those of the famous Schoellkopf family, still associated with the project. But the period of greatest significance at Niagara Falls began with the undertakings of the Cataract Construction Company from which the present Niagara Falls Power Company is derived. In this period decisions of far-reaching importance were made and developments of permanent influence on the power industry were undertaken. Financial, legal, scientific, and engineering talent of the highest order were combined and skillfully coordinated under the leadership of Edward Dean Adams, whose two-volume history, "Niagara Falls," has placed all these matters on record. In the brief space available here it is possible to mention only a few of the significant factors of Niagara development, but these it is important to remember.

Prominent among these factors is the exhaustive effort made by the Cataract Construction Company to secure the best scientific and engineering advice on the proposed development, which led to the formation of the famous International Niagara Commission, whose members—Lord Kelvin, Coleman Sellers, Professor Mascart, Colonel Turrettini, and Professor Unwin—guaranteed its high international reputation.

With the rapid advance of the engineering profession in this country we are likely to forget the acknowledged British and Continental leadership in engineering that sent Dr. Adams abroad in 1890. The subsequent actual developments at Niagara formed an effective step in growing confidence in the capabilities of engineers and manufacturers in this country to undertake large and pioneer projects. Furthermore, Niagara affords an early example of independence of Europe in the financing of such enormous ventures.

To quote from an obituary of the late William Cawthorne Unwin, secretary of the International Niagara Commission, that appeared in the December, 1935, issue of MECHANICAL ENGINEERING—

> The modern age to which the younger engineers now practicing belong finds it hard to understand the uncertainties that faced this commission. For the generation of electricity in large amounts by hydraulic turbines, the transmission of the current generated over long distances, its distribution and use in mechanical and chemical industries, and hundreds of technical problems such as the relative advantages of alternating and direct current were being attacked in pioneer fashion. Nor was it certain that the development should be an electrical one. Electricity was new; it had never been generated centrally in large quantities for distribution over long distances to points where it could be used. While lighting by electricity had been broadly introduced, industrial power was still largely by mechanical means. The Evershed project, upon which the Niagara scheme was based, was entirely hydraulic and contemplated a community of industries deriving their power from individual hydraulic turbines fed from a common canal—the use of power at the site. Mechanical (telodynamic) and pneumatic transmission systems were in a position to contend for consideration with hydraulic, steam, and gas methods of transmission and distribution. Moreover, the machinery and auxiliary apparatus, as well as the construction of the hydraulic details, were of a scale heretofore untried, so that the stakes, engineering as well as financial, were high and hazardous....
>
> Writing 25 years later of the work of the Commission, Professor Unwin said: "The projects were of extremely varied character. Hydraulic turbines of impulse and reaction types of from 2000 to 10,000 horsepower; distribution by electricity, by compressed air, and by wire ropes. Most of the electrical schemes proposed direct-current production and distribution with varying current and constant voltage. Messrs. Siemens proposed constant direct current at varying voltage; Professor Forbes only proposed alternating current. From the first, electrical distribution of the power was in favor, but was not definitely decided upon until May, 1893." Of the significance of the project itself he wrote: "Civilization may be measured by the degree in which human labor is replaced by power derived from natural sources of energy.... At Niagara some 7,000,000 horsepower which might have been available for industrial purposes was being wasted. The conditions were favorable for utilization in other respects for the fall was a high one and the Great Lakes from which the water flows act as reservoirs equalizing the supply. The installation has been carried out with complete success, and it is the first large-scale undertaking of the kind.

> It has been the parent of many others in different parts of the world, or at any rate showed the way to others to achieve a similar success. But the risk of misadventure in so novel and complicated an enterprise in the days when it was carried out was great, and that no serious mistake of judgment or calculation occurred witnesses to the remarkable care with which the preliminary investigations and discussions were conducted."

In the light of present-day influences not the least interesting factor in the history of Niagara power, the significance of which cannot be lightly disregarded, is the rôle played by the government, as represented by the State of New York and the Congress of the United States.

When power was in its infancy and hydroelectric power, with its possibilities of easy transmission to distant markets, was unknown, government paid little heed to what industrialists and promoters were doing at Niagara Falls. Aside from the necessary formalities of granting charters and safeguarding property rights, the state took no part in these developments, nor did it risk money or influence. Only in 1884 did the State of New York bestir itself, and then to create in the neighborhood of the Falls itself a reservation for the benefit of sightseers and the preservation of natural beauties. That the people of the state had any interest in the power resources was not a principle embodied in legislation. Even in 1892 when a limitation was placed by the state on the amount of water that could be diverted for power generation, cheap power for the people was not a question of moment. Scenic beauty, navigation, and national defense were the factors safeguarded.

At the time of the first federal encroachment on the state's rights in water power at the Falls in 1906, under the conservation program of Theodore Roosevelt that resulted in the Burton Act of that same year, preservation of the Falls was the dominant theme. From that year on attempts at regulation and control passed to the federal government, and there followed, in the years named, the International Treaty of 1910, the invocation of the River and Harbor Bill of 1889 in 1913, the enforced consolidation, as a War measure in 1918, of the companies at the Falls, and the Federal Water Power Act of 1920, which established the Federal Power Commission in 1921, whose first license was granted to the Niagara Falls Power Company.

Today, with power a necessity in national economic life, with competitive "yardstick" plants, restrictive and regulatory legislation, high taxation, and an emphasis on low rates and the assumed right of every householder to be served by electrical transmission lines, the contrast of government interest with government indifference when the crucial stages of development were in progress have given Niagara a national significance. In fact, had certain theories of centrally planned capital investments, fortunately not yet adopted, been in force fifty years ago, it may be wondered if any group of engineers and scientists would have been permitted to underwrite the speculative investment which demanded the courage and faith the Cataract Construction Company displayed in 1889.

Today, a country emerging from a world-wide depression of extraordinary severity finds at least one other lesson in Niagara Falls which it may well apply—the development of new industries. For not the least of the collateral benefits of Niagara power was a host of industries that found in cheap, dependable power a means for profitable advancement. Niagara power was developed against the background of a great national depression. The industries and the markets it served assisted in the remarkable economic growth of the country during the first quarter of the twentieth century. What we need today is more such industries, more men of the courage, vision, and ability of those who developed Niagara and its neighbor industries, and greater faith in the nation as a whole in the benefits to be derived from the American system of free enterprise under which these men worked and their projects prospered. These are some of the lessons of Niagara Falls.

Memorial Notices

IN RECOGNITION of loyal support and services to the engineering profession The American Society of Mechanical Engineers annually records memorial notices of its deceased members. Part II of the Society Records, a supplement to the Transactions for August, recently mailed, contains the Memorial Notices for 1936.

Every effort has been made in the preparation of these brief biographical sketches to make them as complete and accurate as possible on the theory that an engineer's professional society should assume the responsibility of placing in its permanent records an adequate memorial to him. For the patient assistance of hundreds of former associates and relatives of those memorialized, the Society has expressed its appreciation privately and publicly, and for the accuracy and adequacy of future notices it solicits the cooperation of all persons having knowledge of the life, work, and associations of deceased members.

Those who turn over the pages of these memorial records will find many that have been prepared by friends and former associates of the deceased. This marks the inauguration of a new policy which the Committee on Publications expects to develop more generally. Obviously the editorial staff is competent to assemble information and check the accuracy of countless details that are matters of fact and record. But only former associates have sufficiently clearly in mind the unique accomplishments and their significance, the proper evaluation of which brings vitality and authority to the obituary. A reading of some of the signed memorials will illustrate the Committee's objective and, it is hoped, convince those who in the future will be called upon to prepare similar tributes to former associates of their privilege to assist in this worthwhile enterprise.

The Committee is proud of the improved quality of its important work and recommends that all members spend some time reading the biographies of their former friends and associates. Comments and criticisms will be appreciated.

Development and Performance of AMERICAN POWER PLANTS

By A. G. CHRISTIE

THE JOHNS HOPKINS UNIVERSITY, BALTIMORE, MD.

THIS PAPER presents a survey of the development of power in the United States during recent years, a discussion of plants and their equipment, some installation and performance data, and trends in design.

1—POWER DEVELOPMENT

Statistics are not at hand of the capacities of industrial power plants, nor of their electrical output. The U. S. Geological Survey compiles annual figures on the production of electricity for public use in the United States of America. These figures were used by A. D. Bailey in an earlier paper (1),[1] and certain of the following curves bring these earlier data up to date. Fig. 1 shows the total kilowatthours produced for public use, the division of this output between water-power and fuel-burning plants, and the ratio of water power to total output. At the end of 1935, the installed capacity in water-power plants was 9,853,800 kw, an increase of 128,000 kw over 1932. At the end of 1935, the capacity of fuel-burning plants was 26,279,300 kw, a decrease of 56,200 kw since 1932, due to retirement of obsolete plants in excess of plant additions.

Consumption of electricity for domestic light and power has increased steadily during the depression. The Edison Electric Institute reports an average annual domestic use of 500 kwhr for 1929 at a cost of 6.33 cents per kwhr, and of 695 kwhr for 1935 costing 4.88 cents. This represents an increase of consumption of 39 per cent in six years, due largely to the more extended use of domestic appliances. Farm electrifications, while desirable, labor under the handicaps of wide scattering of farm homes and of the poor economic conditions of the farmer.

Returning industrial loads will place greater demands for capacity on generating stations than in past years. Improved diversity of domestic service, better power loads, and less reserve capacity in stations due to greater availability of modern plant, may increase the capacity factors in coming years. If one may judge correctly from earlier data through the war years, and from present trends, it would appear that load will grow more rapidly than normal during the next few years until it reaches the projected curve of growth before the depression of 1929. In this case, much additional plant capacity must be added within the next few years.

On the other hand, several new and economical plants have been built by industrial concerns and others are planned. Where by-product steam can be used in industry, such plants are economical investments and may even have secondary power available for sale to the utilities. The effect of such plants upon the central-station industry is still to be determined.

Fig. 2 shows the consumption of fuel expressed as equivalent tons (2000 lb) of coal in electric power plants from 1920 to 1935, and the pounds of equivalent coal burned per kilowatthour. Coals of a wide range from lignite to anthracite are burned in various types of furnaces in the United States of America. The increased use of natural gas for power generation subsequent to 1928 resulted from the construction of many large pipe lines. The fuel consumption in pounds per kilowatthour has decreased only slightly for several years as few new plants have been added, although some old equipment has been retired. It is probable that this average rate will again decrease as new stations and new superpositioned plants are placed in service. Oil, although burned in many plants, seems unlikely to be used to a greater extent due to increasing demands for fuel oil in domestic house heating, for which higher prices can be secured than for bulk supply to power plants.

The selection of a fuel for a given plant depends upon the cost of that fuel delivered at the plant. Consideration must also be given to the so-called "convenience factor," which may enable savings to be made in operating costs when using gas or oil. Many plants have furnaces designed to burn any available fuel or mixtures of fuels.

While steam accumulators have been used for industrial purposes, none has been supplied in the United States of America for central-station use.

2—POWER COSTS TO CONSUMERS

In 1914 the average annual domestic electrical bill was \$22.25 with an average annual consumption of 268 kwhr. In 1935, the average bill was \$33.85 for an annual consumption of 673 kwhr. Consumption increased 151 per cent while the total cost of this electrical service to the consumer increased only 52 per cent. In an earlier discussion (2) it was shown that if consumption were tripled for the same installed capacity—which increased consumption corresponds to the requirements of certain Canadian domestic consumers—the cost per kilowatthour would be about half the present rate. Low rates per kilowatthour are therefore dependent upon improved customer use factors and will be available to consumers when their consumptions have sufficiently increased.

American rates for power cover a wide range of prices and are contingent upon size of load, load factor, power factor, voltage, and to some extent upon competitive conditions. No set of figures can be considered as representative power rates for the industry as a whole.

A factor that mitigates against further decrease in charges for public-utility services is the growing tax burden. According to figures published by the Edison Electric Institute, the ratio of taxes to gross operating revenue increased from 6.31 per cent in 1917 to 14.1 per cent in 1934. Few municipal or government-owned utilities pay taxes and hence rate comparisons with them are unfair on that account. Furthermore, the tendency to place additional taxes upon electrical services is a penalty on progress and a premium on drudgery. The more

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[1] Numbers in parentheses refer to Bibliography at end of this paper.

Contributed by the Power Division for presentation at a meeting, Niagara Falls, N. Y., Sept. 17–19, 1936, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

extended use of electricity lessens human labor and extends the amenities of life.

3—POWER INTERCHANGE

Much thought has been devoted to the interchange of power between the public utilities and private industries and to the utilization of the so-called "dump" or secondary power at times available in industrial plants. Such pooling of power should conserve fuel and warrants careful study wherever excess power is available.

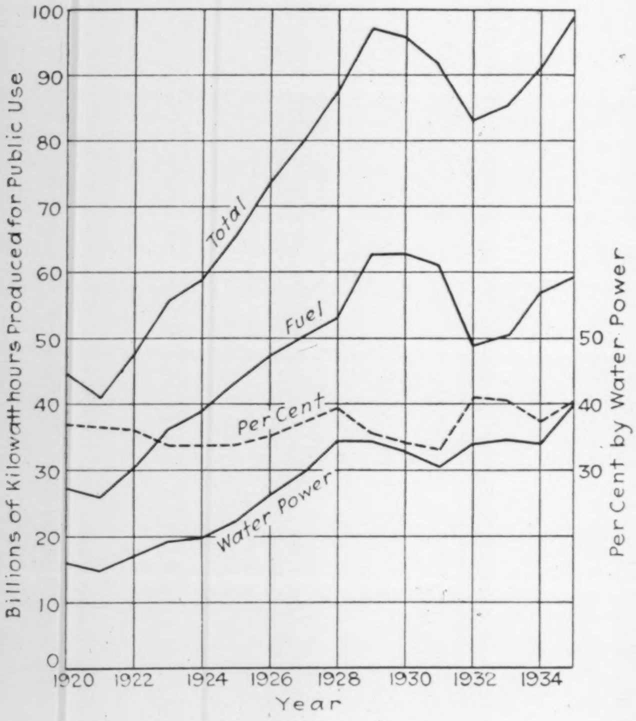

FIG. 1 KILOWATTHOURS PRODUCED FOR PUBLIC USE FROM 1920 TO 1935 AND THE RATIO OF THE PRODUCTION BY WATER POWER TO TOTAL OUTPUT

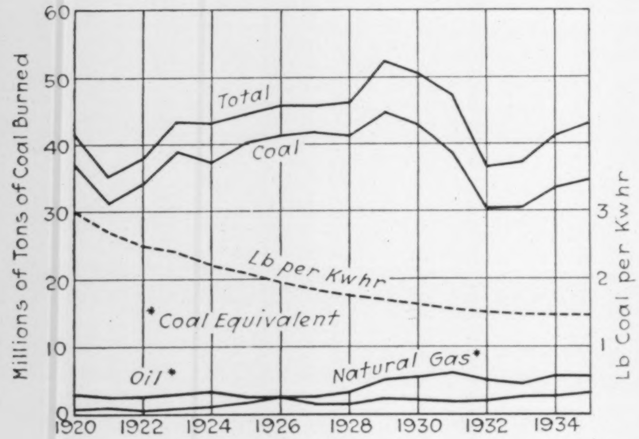

FIG. 2 CONSUMPTION OF FUEL IN ELECTRIC POWER PLANTS OF UTILITIES FROM 1920 TO 1935 AND THE FUEL RATE IN POUNDS PER KILOWATT HOUR

Due to the fact that most hydroelectric plants form parts of large systems interconnected with thermal plants, virtually the whole hydro output can be utilized and there is little secondary power available. Few electric boilers are installed to use secondary power in the United States.

Conditions have been favorable for power interchange between public utilities and industrial plants in the United States. In certain cases, discussed in recent papers (3, 4), some generating plants are jointly owned by a utility and an industrial concern, where electricity and steam are delivered from the same plant to one or both owners.

More interchange of power has not been developed due to a lack of common understanding of the technical and economic factors involved. The party to whom the proposal is made often suspects that some advantage is sought by the proposer. Power interchange or sale has economic advantages to both parties in many cases where the problem is examined without prejudice and where both parties share in the gains.

The difficulties in effecting an economic interchange of power are in general:

(*a*) The excess power from the industrial plant is not always available at the time of the utility's peak load, and therefore cannot be considered as prime power replacing investment in the utility's plant. Under such circumstances, secondary power is only worth to the utility the incremental cost of generating the same output in the utility's plant, which virtually amounts to fuel cost only.

(*b*) Problems of coordination of operation arise. Industrial operation is governed largely by business conditions and the industrial plant may be closed down seasonally or during business recessions. Such conditions place a low money value on secondary power available from industry.

The sale of steam for domestic and commercial use is increasing and this offers possibilities for the generation of surplus power at low cost.

4—WATER POWER

Some large hydroelectric plants have been constructed during the last few years or are under construction, as shown in Table 1. This building program has been fostered largely by the United States Government which has embarked upon an extended plan for electrical development.

Heretofore, with few exceptions, large hydroelectric plants were developed where their output could be supplied to metropolitan centers or could be absorbed by a group of power systems covering contiguous territory. The government departed from this practice in selecting sites to be developed in which an outlet for the large amounts of power available is not apparent in some cases unless privately owned systems in neighboring territory are eliminated or absorbed.

The power from Boulder Dam will be transmitted to districts in Southern California around Los Angeles. The power from Norris and Wheeler dams together with that from the older Wilson Dam on the Tennessee River will be distributed in the Tennessee Valley and in the district between it and the Mississippi River. The other government plants are located in the western and middle western states. In view of the existing surplus of power in Canada and the possibility of additional developments at other sites, there does not seem to be any probability of power development on the international section of the St. Lawrence River in the immediate future.

Considerable doubt exists in regard to the economic justification for many of these government projects. In the case of the Tennessee Valley projects, navigation and flood control have been charged with certain shares of the cost, which in the case of privately owned utilities would have been borne by the

TABLE 1 RECENT LARGE HYDROELECTRIC PLANTS, UNITED STATES AND CANADA

Plant and Company	State or Province	River	Capacity in horsepower Initial	Capacity in horsepower Ultimate	Static head, ft	Type of wheel	Year of initial operation
Columbus, Loup River Pub. Pr. Dist.	Neb.	Luop	54,000	54,000	14	Francis	1937
Sutherland, Platte Valley Pub. Pr. & Irr. Dist.	Neb.	No. Platte	36,000	36,000	67	Francis	1936
Hawk's Nest, New Kanawha Pr. Co.	W. Va.	New	140,000	175,000	...	Francis	1936
London, Kanawha Valley Pr. Co.	W. Va.	Kanawha	20,850	20,850	...	Propeller & Kaplan	1936
Marmet, Kanawha Valley Pr. Co.	W. Va.	Kanawha	20,850	20,850	...	Propeller & Kaplan	1936
Norris, U. S. Tenn. Valley Authority	Tenn.	Clinch	132,000	132,000	266	Francis	1936
Wheeler, U. S. Tenn. Valley Authority	Ala.	Tennessee	45,000	360,000	68	Propeller	1936
Hamilton, Central Texas Hydro-Electric Co.	Tex.	Colorado	30,000	45,000	154	Francis	..
Boulder Dam, U. S. Bureau of Reclamation	Ariz.-Nev.	Colorado	515,000	1,835,000	730	Francis	1936
Caspar Alcova, U. S. Bureau of Reclamation	Wyo.	No. Platte	42,000	42,000	260	Francis	1939
Diablo, City of Seattle	Wash.	Skagit	166,000	332,000	387	Francis	1936
Bonneville, U. S. Government	Wash.-Ore.	Columbia	137,000	665,000	170	Kaplan	1937
Beauharnois, Beauharnois Lt. & Pr. Co.	Que., Can.	St. Lawrence	440,000	636,000	31	Francis	1932
Safe Harbor, Safe Harbor Water Pr. Corp.	Pa.	Susquehanna	261,000	510,000	65	Kaplan	1931
Rock Island, Puget Sound Pr. & Lt. Co.	Wash.	Columbia	84,000	210,000	80	Propeller	1933
Grand Coulee, U. S. Bureau of Reclamation	Wash.	Columbia	.....	2,500,000	500	......	1938
Rapide Blanc, Shawinigan W. & Pr. Co.	Que., Can.	St. Maurice	160,000	240,000	150	Francis	1934
Masson, MacLaren-Quebec Pr. Co.	Que., Can.	Lievre	136,000	136,000	66	Francis	1933
Abitibi, Ont. Hydro-Elec. Pr. Comm.	Ont., Can.	Abitibi	132,000	330,000	294	Francis	1933

generating plant. With ample highways and railroads for the district served, it is difficult to justify these outlays for navigation. Other rivers need flood control more urgently than the Tennessee. Some government developments, such as those on the Columbia River, could have been delayed until some future date, when an adequate demand for power would have been developed. The Passamaquoddy tidal-power project in Maine appears to have no economic justification.

The government projects are located in sections of the country that are not highly industrialized and with the exception of Los Angeles there is no large city to be served by these plants which does not already have adequate supplies of water power. For this reason, any growth in power demand in the highly industrialized areas in other sections of the country will have to be met by the construction of fuel-burning plants.

Certain of the privately owned hydroelectric plants are capable of further extension as low-cost peak-load plants when system base loads increase, necessitating system additions, and the value of storage is thereby enhanced. The principal difficulty with many of such plants is the variable seasonal flow of the rivers and the lack of storage and control at their headwaters. Had the government undertaken flood control and storage on these rivers, the output of the hydroelectric plants which are already developed could have been increased under coordinated control.

Newer hydroelectric plants have been characterized by some large turbines and generators. Operating characteristics have been improved and better efficiencies over a wide range of load have been possible. The use of Kaplan wheels has increased during the last few years.

The cost of plants has been reduced in several cases by placing the generators in the open air. The hydraulic turbines are generally fully enclosed in the plant. The use of outdoor electric switching plant and transformers is common practice at hydro plants.

The output of hydroelectric power plants as shown in Fig. 1 has averaged 36.7 per cent of the total power generated. During the last few years it has averaged about 40 per cent. In 1935 the generator capacity of hydroelectric plants serving the public was 9,853,800 kw out of a total capacity of all plants of 36,133,100 kw, or 26.5 per cent of the total. This indicates that the base loads were carried as much as possible by hydro and peak loads by steam.

Privately owned utilities are undertaking few plants in view of the development program of the government. Reconstruction of older small hydro plants, particularly in the New England district, and in some cases the installation of Kaplan-type turbines in these plants, has resulted in increased capacity and efficiency. New plants will probably be developed at a few favorable locations where small capacities are available.

Hydro reduces the stand-by reserve on a large system, for the hydro units can be started up and synchronized on the line in a few minutes. The correlation of hydro and steam power has been discussed by F. A. Allner (1).

5—INTERNAL-COMBUSTION ENGINES

Many internal-combustion engines, principally of the Diesel type, have been built in the last few years. Few have been of large capacity. About 20 per cent of the Diesel engines built are for marine use. General industry has taken almost an equal amount. Another 20 per cent has been about equally divided between public-utility and municipal plants. The remainder are for railroad, automotive, and other services. Many oil engines have been sold recently to government-financed municipally owned plants in the smaller cities. Estimates of the production of Diesel engines for all purposes for 1935 was 1,000,000 hp.

Public utilities strongly opposed, in former years, the development of the Diesel engine, fearing that it would replace central-station service in industrial plants. The place of the Diesel as a source of power for public utilities in remote localities, at the ends of transmission lines, as house reserve units, and as stand-by, is better understood at the present time, and an increasing number may be used by the utilities, particularly when the reliability of the modern high-speed units has been demonstrated.

The largest Diesel station in the United States is the municipal plant at Vernon, Calif., which contains five 7000 bhp, Hooven, Owens, and Rentschler, double-acting, two-cycle units driving 7000-kva generators at 167 rpm. One of these engines on test produced a net brake horsepower-hour on

0.371 lb of fuel oil. This is equivalent to about 10,000 Btu per kwhr. This figure is representative of best performance for solid-injection engines under sea-level conditions and 68 F, with 10,800 Btu per kwhr as representative of air-injection engines. Lubricating-oil consumption, which is high on Diesel engines, becomes a significant element in the cost of operation. Where long life and reliability are desired, engines with a mean effective pressure between 65 and 70 lb per sq in. are often specified.

To indicate the advances made in Diesel design, one manufacturer states that in 1915 air-injection engines were built weighing 400 lb per bhp which used 0.41 lb of fuel oil per bhp-hr. Their present standard heavy-duty stationary engine weighs about 200 lb per bhp, uses about 0.36 lb of fuel oil per bhp-hr, and has mechanical injection.

Most large Diesels operate on the two-stroke cycle, while small ones use the four-stroke cycle. Some of the largest engines are double acting. The tendency in recent designs has been to increase rotative speed and decrease weight per horsepower. Engines have been simplified, combustion characteristics improved, and efficiency increased. Many designs of engine are entirely enclosed. Both trunk pistons and crosshead types are used.

Solid injection at pressures of from 4000 to 8000 lb per sq in. is becoming standard practice where high-grade fuel oils are used. Low-grade fuels can be burned best with air injection. Superchargers have not been employed to any extent in American practice. Recent developments indicate that the output of the engine can be increased about one third by supercharging with no sacrifice in fuel economy, no serious rise in pressure, and no appreciable increase in exhaust-gas temperature. Since supercharging provides added capacity at a small increment in cost, it may be used more extensively in future installations, particularly to enable peak loads to be carried.

The use of filters on the air suction and of centrifuges on the fuel-oil and lubricating-oil supplies is increasing. Forced lubrication, even to the valve gear, is becoming general practice. Greater attention is paid to the various essential auxiliaries. Automatic starting devices, initiated by pressing a button, have been employed. The general trend in Diesel development has been to reduce investment per kilowatt.

One manufacturer has built and tested a gas-burning Diesel engine operating on a cycle of its own. This may further enlarge the field of the Diesel. Light-weight high-speed Diesels for locomotive, truck, and tractor service have been introduced and are under continuous development. These fields offer much promise for extended use of this prime mover.

Max Rotter states (5) that in general structure, large Diesels are approaching a conventional design, a bedplate forming a bottom girder, a cylinder block forming a top girder, frames between the bedplate and the cylinder block, and tie rods joining these parts into a structure of great strength and rigidity.

The operating life of Diesel engines must be estimated closely to provide a proper depreciation allowance. While some engines have shown long life, others have operated only a comparatively few years. Recent estimates of useful life range from 10 to 15 years, though this may be exceeded by newer engines.

Attempts have been made to standardize fuel-oil specifications for Diesel engines and considerable progress has been made. Recognition is given to the importance of ignitability of the fuel oil.

Diesel engines will become an increasingly important factor in power development unless progress is checked by increased fuel-oil prices due either to new taxes or to actual shortage of oil supply.

Natural-gas engines have increased in use due to the low cost and wide availability of natural gas. A number of cities have installed gas engines at their sewage-disposal plants to utilize the gases from sewage for the generation of the power needed around the plant.

6—STEAM POWER PLANTS

In 1935 the total capacity of steam plants generating electricity for public use was 25,708,200 kw, a decrease of 139,000 kw since 1932, since retirements of old plant exceeded additions of new equipment. While the output of fuel-burning plants for 1935 as shown by Fig. 1 has not equaled that of 1929–1932, the output for the first half of 1936, together with drought conditions, indicates that the kilowatthour production of such plants for 1936 will probably exceed any previous record. When consideration is given to increased hydro capacity connected to the various systems and to the increased reliability of steam generating plant, sufficient reserve plant seems available for present conditions. Additional load will call for new plants or additions to old plants and many utilities have already prepared plans to meet this demand.

Few new plants have been built by utilities since 1932. Buzzard's Point, at Washington, D. C., Port Washington near Milwaukee, the 165,000-kw turbine installed in Richmond Station, Philadelphia, the Provo outdoor station of the Utah Power Company, Provo, Utah, and the reconstruction of Conner's Creek at Detroit are among the principal recent additions to utility steam plants, although extensions to many existing stations are under consideration. A considerable number of turbines, many of the back-pressure type, have been installed in industrial plants; the 110,000-kw condensing turbine and the 15,000-kw noncondensing unit added by Ford Motor Co. to River Rouge plant and the 10,000-kw back-pressure turbines at Firestone Tire and Rubber Company and Weirton Steel Co. are examples of this new equipment.

Engineers have had opportunities to study the performances of various station cycles and to analyze the economic and technical questions involved in the planning of new plants. When new demands are made for increased generating capacity, they can state with more assurance what type of plant and what capacities should be installed, and where and when additions should be made.

LARGE OR SMALL STATIONS

Large, so-called "super power" stations have been added to many power systems in the United States. The rapid growth of load, the increasing efficiency of newer apparatus, and the unit costs of large equipment were factors influencing the construction of such stations.

Some have suggested that plants of smaller capacity should be built on the unit system in strategic locations adjacent to load centers. Transmission costs would be decreased, danger of outage lessened, and reliability of service increased. Plant additions could be made more proportionate to the increase of load than in large stations. The cost of delivered power for the system as a whole might be reduced by the smaller stations.

Further study of each system and the consideration of local conditions will govern future decisions on large or small stations.

ECONOMIC PROBLEMS

High taxes and the need for decreased electrical rates to consumers to meet the government "yard-stick" of rates necessitate the construction of the lowest cost plants at present possible with full consideration of thermal economy, reli-

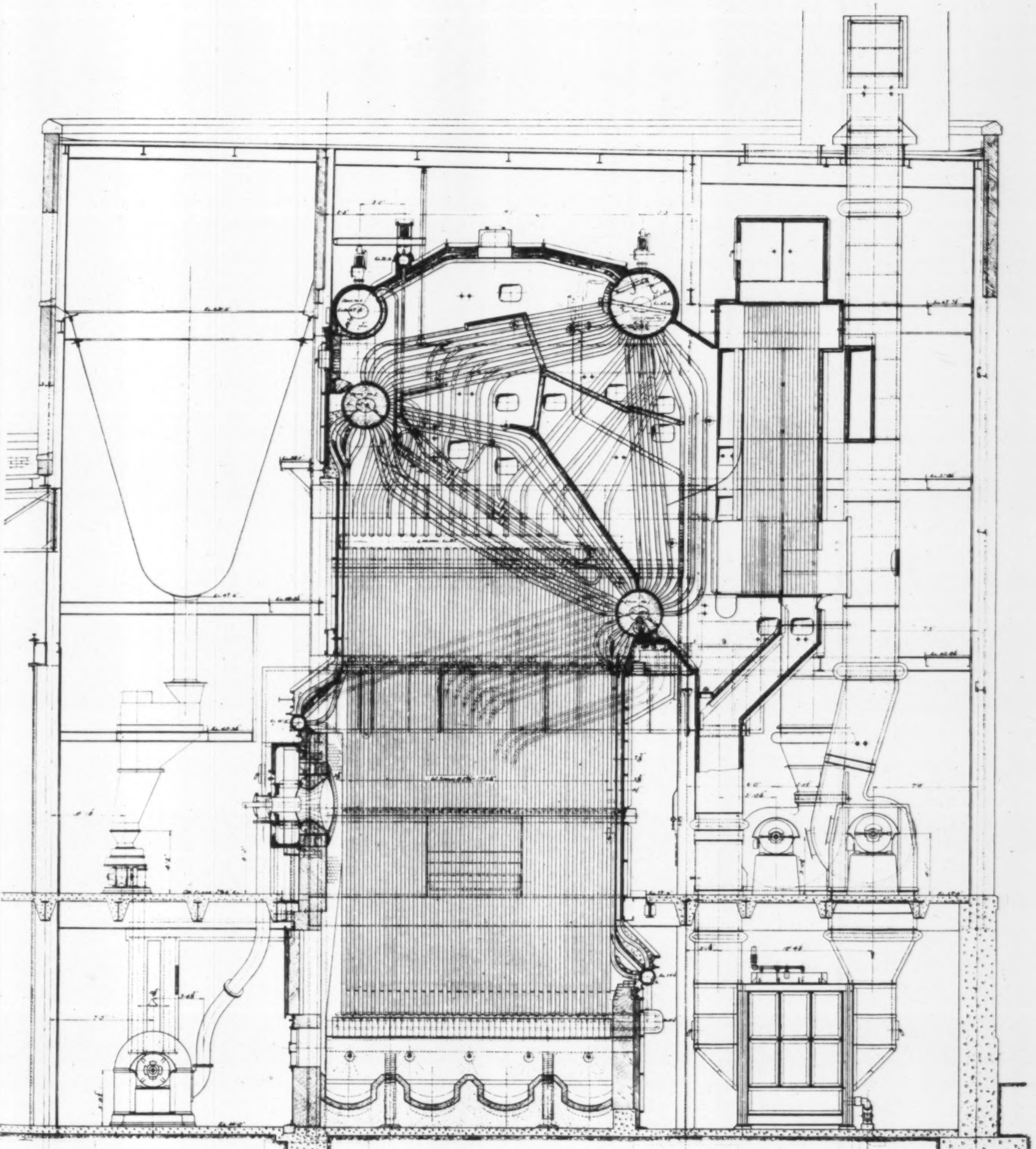

FIG. 3 RILEY STOKER CORPORATION'S RING-FLOW, BENT-TUBE BOILER—INSTALLED AT TITANIUM PIGMENT CO., SAYREVILLE, N. J.

(See Table 3 for data.)

ability, and availability. Hence much attention is given to fixed charges and to operating costs.

In evaluating new plants, estimates must be made of the effect of each upon the system as a whole. The transference of load from the older to the newest station leaves the former to operate at lower capacity factors, lower loads, and poorer economy. The economies of the new plant must therefore be based upon increment gains for the whole system, and these savings must control all decisions regarding investment in new plant. Justification of equipment added to existing plants to effect marginal savings should also be based upon the increment system gain. ■

Increased and substantially equal reliability of both boiler and turbine plant has had two effects; less duplication is provided for reserve and unit plants of one-boiler-per-turbine are in operation. One of the first "unit" stations was the Gould St. station of the Consolidated Gas, Electric Light, and Power Company, Baltimore, Md., where two boilers and two turbines, each of 36,000-kw capacity, were installed. The Port Washington station of the Milwaukee Electric Railway and Light Company, Milwaukee, Wis., has one boiler and one 80,000-kw turbine. This station was placed in service at the end of 1935, and has since established a performance record for steam central stations of 11,166 Btu per kwhr output for the first six months of its operation, as shown in Table 2. Each of these stations forms a part of a separate large interconnected system.

RECONSTRUCTION OF OLD STATIONS

In the effort to lower power costs, consideration has been given to the possibilities of reconstructing older power stations that are characterized by smaller boilers and furnaces, lower operating steam pressures and temperatures, and fewer heat-recovery devices than the newer stations. Equipment changes have been made in some of the older stations that improve efficiency, but, as a rule, these improvements could only be justified where the change increased the generating capacity of the station at a lower cost than in a new plant.

For example, new stokers in enlarged rebuilt furnaces together with changes in boiler-tube arrangement and the addition of radiant superheaters on a portion of the boilers at the Westport station, Baltimore, Md., not only improved boiler performance but permitted the addition of two 20,000-kw turbogenerators to this old plant. Also changes in some of the earlier boilers at Cahokia station, St. Louis, Mo., consisting largely of additions of water-cooling surface to the furnaces, resulted in sufficient added steam-generating capacity to permit the replacement of a 30,000-kw unit by a 75,000-kw turbogenerator.

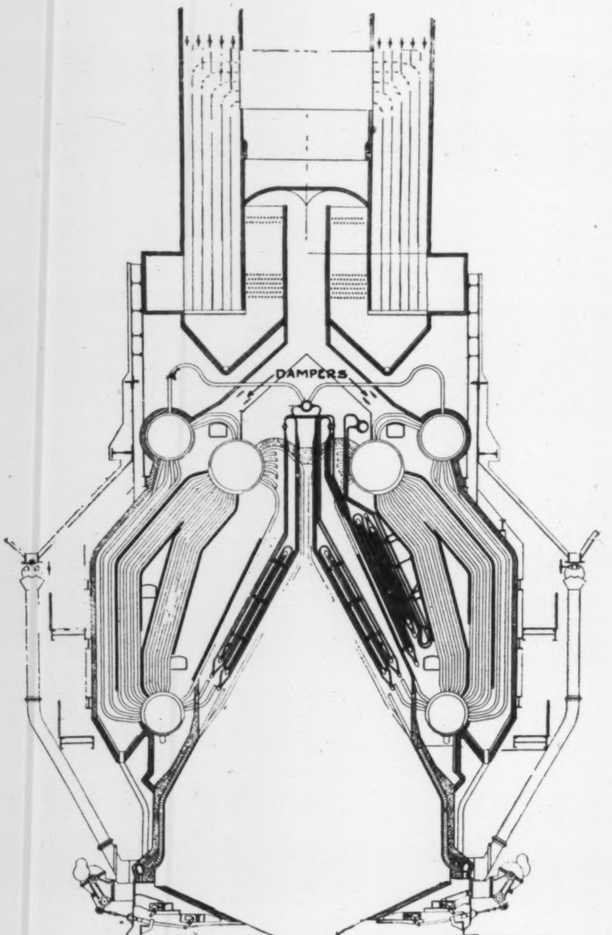

FIG. 4 TAYLOR UNDERFEED STOKERS AT CONNERS CREEK STATION, DETROIT EDISON CO., PROVIDED WITH ZONED AIR CONTROL (See Table 3 for boiler data.)

A notable example of the rehabilitation of an old station is the Conners Creek plant of the Detroit Edison Co., which has been fully described in recent articles (6). The existing building, traveling crane, turbine foundations, cooling-water intake and discharge tunnels, condensers, electrical distribution circuits, and certain auxiliaries, have been retained. The old low-pressure boilers, which operated at 220 lb per sq in., 600 F, have been replaced by new boilers for 600 lb per sq in., 850 F. Parts of the existing turbogenerators have been built into three reconstructed units of larger capacity with extraction heaters which, combined with the better efficiency under the new steam conditions, cause the flow to the retained condensers to be nearly the same as under the former conditions. The old station had a total generating capacity of 180,000 kw. The reconstructed station will contain three rebuilt 30,000-kw units and four or five new 60,000-kw units, a total of 330,000 or 390,000 kw.

THERMAL PERFORMANCE

The theoretical and practical aspects of the various available thermal cycles have been ably presented in other papers (7, 8, 9, 10, 11). The regenerative, reheating-regenerative, and the binary-vapor cycles have been applied in stations and their advantages, limiting factors, and relative efficiencies are generally understood. Data on the equipment and the performance of 15 stations were given in an earlier paper (1), and these operating figures are representative of performance since that time, except as modified by changing capacity factors. Data on 12 additional stations are presented in Table 2.

The data in Table 2 and in the earlier paper (1) present results under various cycles and conditions. Table 2 includes one noncondensing, three superposed, one rebuilt, and several high- and moderate-pressure stations. Capacity factors vary from 11.7 to 72.6 per cent; the low figures generally belonging to plants operating in parallel with hydro systems. Northeast station and Edgar station contain low-pressure capacity in excess of that corresponding to the high-pressure units, which fact influences station performance. Spinning reserves and auxiliary operation during stand-by to hydro also increase heat rates. The ratio of auxiliary power to gross production varies with station cycle and with the extent of the stand-by periods.

The trend in station design is toward the use of higher steam pressures and temperatures. The construction of such plant may lead at the moment to higher cost of installation, but the normal tendency of such costs should be downward as equipment becomes standardized. The better fuel economy of the high-pressure, high-temperature plant usually justifies any additional first cost when the increment costs of the system as a whole are considered.

Stations with pressures up to 1800 lb per sq in., 1000 F total steam temperature, have been discussed and boiler and turbine manufacturers are prepared to bid on such equipment. However, the present tendency is to select 1200–1400 lb per sq in., 900–925 F, as reasonable station conditions for new large stations with 650–800 lb per sq in., 850 F, for the smaller plants; the latter are discussed in the paper on the trend of design in

500 to 800 lb pressure steam-electric stations by J. A. Powell,[2] being presented at this meeting. New stations will probably operate upon the regenerative cycle with no intermediate steam reheating. Steam will be extracted at a number of points, to give the desired temperature of the feedwater leaving the last heater. This temperature is dependent upon the costs of boiler, economizer, heaters, and auxiliaries, as well as that of fuel. Two to five extraction heaters have been used.

The earlier 1200–1400 lb per sq in., 750 F, stations operated on the regenerative-reheating cycle. One of the latest stations, Port Washington, also operates on this cycle, and its performance as shown in Table 2 is excellent. One may ask why this cycle is not used in other new plants. Reports from various stations using the reheating-regenerative cycle indicate that no serious difficulties have been encountered in service. Turbines can be taken off and put on the line again as load conditions require with the same assurance as with turbines operating on the regenerative cycle only. The use of the reheating-regenerative cycle in new stations employing the higher steam temperatures may lead to higher thermal efficiency than the straight regenerative cycle, but this saving is partly offset by the additional expense of reheater piping and superheater. The regenerative cycle is often used when low investment is imperative and when the initial temperature is such that moisture at exhaust is not excessive.

Binary-vapor cycles employing various substances for the high-temperature elements have been considered. The Dow Chemical Co. employ diphenyl oxide for a superheating and reheating medium. At Bremo Bluffs station of the Virginia Public Service Co., diphenyl oxide is used as a transfer medium to recover the heat in the flue gases and to transfer this heat to the air entering the furnace. Mercury-vapor plants are discussed later.

SUPERPOSED PLANTS

The term "superposition" has been given to a form of plant rehabilitation. Superposition consists of the addition of new high-pressure high-temperature boilers that furnish steam to a high-pressure turbine which exhausts into the lower pressure steam main and then to the older turbines. The latter, as the low-pressure units of the combined set, expand the steam to condenser pressure. Superposition thus increases the capacity of the station and at the same time greatly increases the thermal efficiency, for the steam is now expanded through a greater heat drop.

Superposition is not a new idea. Its present vogue is the result of recent metallurgical developments which have made possible the production of steels suitable for the high temperatures needed in the new plants. Operating conditions vary widely in the older stations where superposed plants are considered. The new boiler pressure and temperature are chosen such that the exhaust conditions of the new turbine will approximate present initial conditions for the older turbines. For the larger stations initial conditions of 1200–1400 lb per sq in., 900–925 F, are generally considered, though a temperature of 1000 F may be used. These conditions apply to the larger plants at present operating at 200–400 lb per sq in. pressure and steam temperatures of 550–750 F. Superposition will seldom be applied to old stations where the equipment is inefficient or practically obsolete. Neither will it generally apply to stations built within the last ten years, for these have good efficiency and may not justify the superposed plant. For small stations with 200-250 lb per sq in. pressure, the new steam conditions for the superposed plant may be 650–850 lb per sq in., 825–850 F.

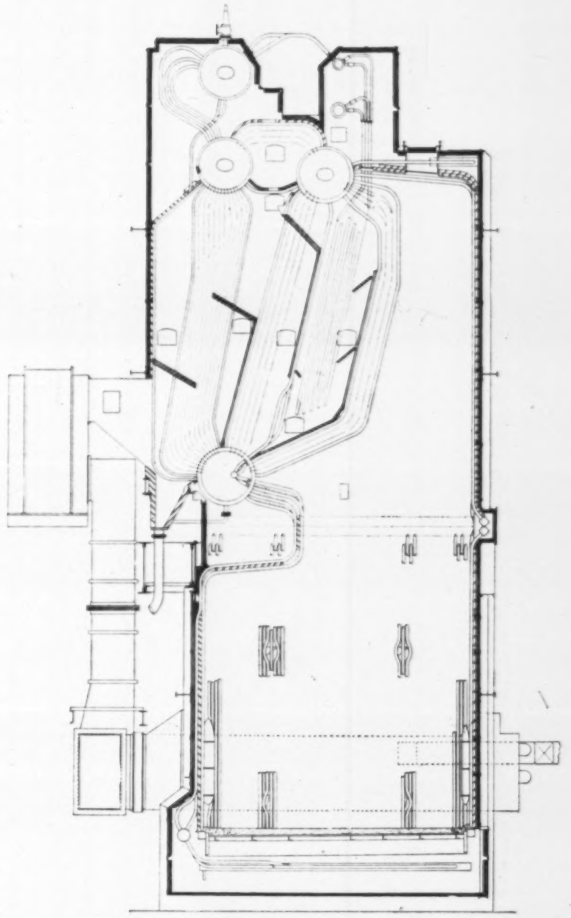

FIG. 5 COMBUSTION ENGINEERING CO.'S 4-DRUM, BENT-TUBE STEAM GENERATOR FOR 12TH ST. STATION OF VIRGINIA ELECTRIC AND POWER CO., RICHMOND, VA.

A modified regenerative cycle will generally be used in superposed plants, that fits the local conditions of the old plant which may contain turbines with no extraction heaters and with steam-driven auxiliaries. In some cases, it may be economical to add extraction heaters to the older units and also to provide one or more feed heaters on the new superposed turbine.

The investment in superposed plant varies with local conditions. It is seldom justified by the thermal savings alone, but increased capacity can generally be secured at a lower unit cost than by a new plant, the combination resulting in lower increment system costs. No new condensing plant is required and the present electrical distribution system can be utilized. The size of the added superposed units can be selected to fit load growth more closely than the larger units that would be chosen in a new plant. Also, furnaces and boilers frequently deteriorate more rapidly in service and become obsolete sooner than turbines and condensers. These boilers can be replaced by the high-pressure steam generators for the superposed plant, and the whole plant given an extension of life at an improved heat rate. Superposition with new boiler plant justifies the extended use of the older turbines which can seldom be scrapped as long as peak and reserve capacity is needed. This plan utilizes land, intake and discharge water facilities, coal- and ash-handling plant, part or all of buildings, and the transmission equipment. The capacity of plants with limited cooling-water supply may be increased by superposition. Finally, the overall

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[2] See pages 573 to 576 in this issue.

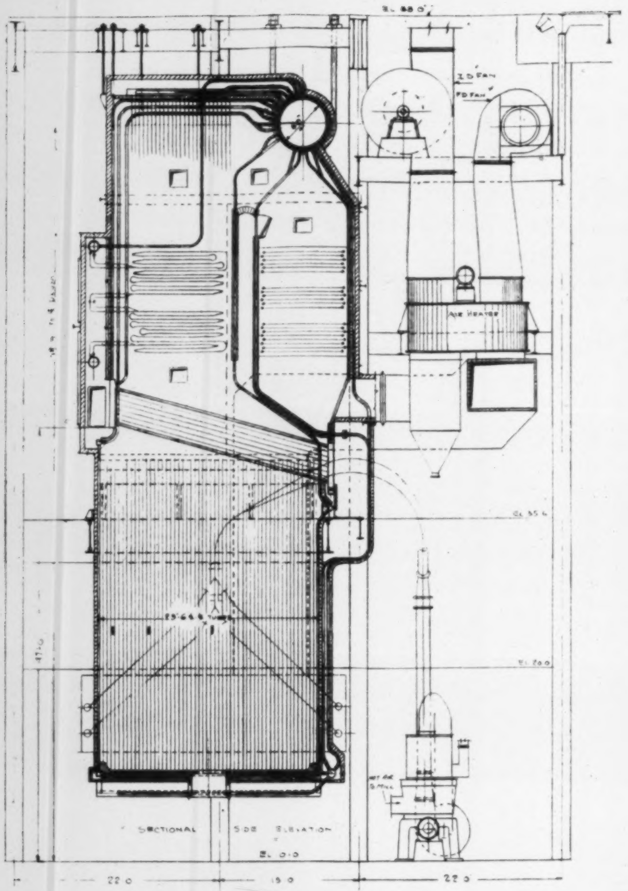

FIG. 6 COMBUSTION ENGINEERING CO.'S CROSS-DRUM SECTIONAL-HEADER STEAM GENERATOR FOR WATERSIDE PLANT NO. 2, NEW YORK EDISON CO., NEW YORK, N. Y.
(See Table 3 for details.)

efficiency of the superposed plant may be higher than any other plant on the system, and, as a consequence, it will again become a base-load station with due consideration of system increment loading.

While superposition may permit the use of the older boiler-house structure and boiler foundations, it may be desirable to hold the old boilers in reserve and to build an addition for the new high-pressure boiler and turbine. Superposition is more fully considered in E. H. Krieg's paper[3] on that subject, presented at this meeting.

BUILDINGS

The architectural design of the newer power stations provides more pleasing lines and more attractive appearance than older plants. Landscaping is also done where possible further to enhance appearance.

Modern steam-generating units as a rule require a tall building. Dust-catching equipment presents a problem in many cases, as this is generally placed above the boiler plant and is difficult to screen from view. Where land is cheap this apparatus may be placed at ground level.

Chimneys, of steel or reinforced concrete, usually start from the boiler-house roof and are carried by the building steel work. Height usually varies from 250 to 300 ft above the furnace to secure ample dispersion of the discharged gases.

No division wall is placed between boiler and turbine room in many plants. No difficulties have arisen in plants where this wall is omitted, as few moving parts of modern units are exposed.

All parts of the plant are kept scrupulously clean, often by vacuum cleaners. Ample natural or artificial lighting is provided. This is aided by aluminum paint on steel work and by light-colored interior walls and floors. Galvanized expanded-metal gratings are used for operating galleries and stair treads. Heating and ventilation are also provided in northern plants. Roofing materials are employed that will not cause condensation in winter.

Proposals have been made to construct an outdoor plant without the usual boiler- and turbine-room walls and roof. It was thought that this would lead to lower plant investment, but the possible savings do not appear to be large. Comfort in winter would be sacrificed and difficulties would arise with maintenance and repairs. The outdoor plant would be more suitable in southern locations than in the North or Mid-West.

This discussion of the outdoor plant has led to the study of methods to reduce the volume of power stations. Buzzard's Point station at Washington, D. C., is an example of low height with air preheater and dust catcher placed behind the boilers rather than above. F. S. Clark, in a recent paper (12), suggests that turbines be provided with side exhaust outlets and that condensers be placed horizontally at the side of the turbine rather than under the turbine. This would effect a substantial reduction in turbine-room height, lessen the cost of turbine foundations, and improve operating facilities.

COAL AND ASH HANDLING

Coal reaches power stations either in barges or in railroad cars containing about 50 tons each. It is removed from the former by clam-shell buckets operated from unloading towers which usually also contain crushers or breakers. At large stations, electrically operated car dumps turn the car upside down over a hopper. Drop-bottom cars unload directly into hoppers at the smaller stations. Bradford breakers are used in the larger stations to reduce the coal to the desired size. Rolls, jaw crushers, and hammer mills are also employed.

Skip hoists or bucket conveyors elevate the coal in many plants. Belt conveyors rising from ground elevation to the top of the bunkers are economical in the larger stations. Belt conveyors generally distribute coal over bunkers.

Many power stations have large coal-storage areas as a reserve against failure of the transportation system, strikes, and other interruptions. Various devices, such as telpher systems, drag scrapers, locomotive cranes, are available for placing coal on these storage areas and also for reclaiming it.

A problem with coal storage is spontaneous ignition in the piles. Many methods are employed to prevent fires. The plan of spreading the coal evenly over the pile and then compacting it with a road roller has been fairly effective. In some places, underwater storage has been used. This has limitations in the North due to severe frost conditions.

Suspended bunkers of catenary section have been used for inside coal storage. Huntley No. 2 station, Buffalo, N. Y., has only outdoor coal storage adjacent to the boiler room, which is said to have been satisfactory under severe winter conditions. Coal silos at the side of the boiler room are low in first cost, but frequently cut off light from the boilers.

Ash, whether from stokers or from wet- or dry-bottom furnaces, is generally handled in newer stations by hydraulic sluicing, as shown in Table 2. This reduces labor costs, diminishes the dust nuisance, and permits lower boiler-room heights, as ash bunkers and car runways are not necessary.

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[3] See pages 562 to 572 in this issue. For a paper describing a superposition plant see also pages 585 to 590.

Ash disposal depends upon local conditions. In some cases stoker ash is made with portland cement into "cinder block," a building material. Ash is used for filling in low ground, for embankments, and other purposes. A commercial outlet for ash and cinders from powdered-coal furnaces is being sought. Some applications of this material for building blocks, road surfacing, and fillers have been developed.

STEAM-GENERATING PLANT

No equipment has undergone a greater transformation in the last 20 years than steam-generating plant. In place of a number of boilers of small steaming capacity operating at pressures of from 200 to 250 lb per sq in., one may find a single large boiler, operating at 1400 lb per sq in., 900 F, with a steaming capacity up to 900,000 lb per hr, as shown in Fig. 7. Stoker practice has completely changed and pulverized-coal firing has been established. Steam temperatures have increased, and the use of air preheaters and economizers, singly or together, is common. Typical steam-generator installations are shown in Figs. 3 to 12.

No physical difficulties arise in the construction of boilers for any desired pressure since the metal temperatures in the boiler itself are not high. Once-through coil-type boilers for experimental purposes have been built for pressures as high as 5000 lb per sq in. Forced circulation has not been used in large boilers, though it has been successfully applied in the Ryan oil-fired boiler which has been built to date only in small capacities at 600 lb per sq in. The commercial boilers with the highest operating pressures in the United States, i.e., 1800 lb per sq in., are in the plant of Philip Carey Co., Cincinnati, O. Many stations have boilers operating at 1200–1500 lb per sq in., and more are in construction.

A substantial gain in thermal economy results from increases in superheat. Hence there is a desire to approach the limit of permissable temperature. This limit is fixed by the metals available. New alloys permit the use of a steam temperature of a 1000 F and may eventually permit 1200 F. Reliability and continuity of superheater operation must be maintained, and first and operating costs must not be prohibitive. Hence conservatism prevails in applying the limiting temperatures. With the definite trend toward higher superheat, the relative proportions of evaporating surface and superheating surfaces are altered.

In Table 3 are presented data upon 29 recent installations and boilers under construction, with a wide range in steam capacities. Eleven operate above 1200 lb per sq in. pressure; twelve more operate at pressures in the 600–900 lb per sq in. range; seven at 900 F or over, and all but nine use pulverized coal. A study of these figures shows a wide divergence in the relative proportion of the parts of the steam-generating unit, and in furnace size, type, and combustion rates. In the case of the Millers Ford, Fig. 9, and Springdale, Fig. 10, boilers, both the superheaters and economizers are greater in area than the combined boiler- and water-wall surface. The inter-relations of furnace design, waterwalls, furnace temperature, convection surface, and superheat have been discussed in a recent paper by F. H. Rosencrants (13).

It will be apparent from Table 3 that there is no accepted standard for the division of the heating surfaces between waterwall, convection boiler, superheater, economizer, and air heater. Each case is an individual problem, and boiler manufacturers are still seeking data upon the proper disposition of heat-absorbing surface. This disposition is determined by the combination that gives satisfactory results at the lowest price and is influenced by the cost of fuel, type of load, steam pressure and temperature, superheater design, feedwater temperature, degree of air preheat, desired efficiency, and furnace maintenance.

The limiting capacity of boilers is an intangible figure, dependent upon the arrangement of heating surface and baffles, steam-liberating area of the drum, limiting draft loss, the heat-generating capacity of the furnace, the choking of gas passages, and the limits of boiler-drum manufacture. At present, the largest steaming capacity appears to be about 1,250,000 lb per hr, but this is only to be regarded as a temporary limit.

Both straight-tube and bent-tube boilers have been used for high-pressure service. The bent-tube type has been favored in recent installations, 20 of the 29 boilers in Table 3 having bent-tube construction. Some of the older straight-tube boilers developed difficulties with water circulation in the tube bank. Poor circulation in boiler tubes leads to high metal temperatures and rapid corrosion. Recent straight-tube boilers have had the cross drum placed at a high elevation relative to the convec-

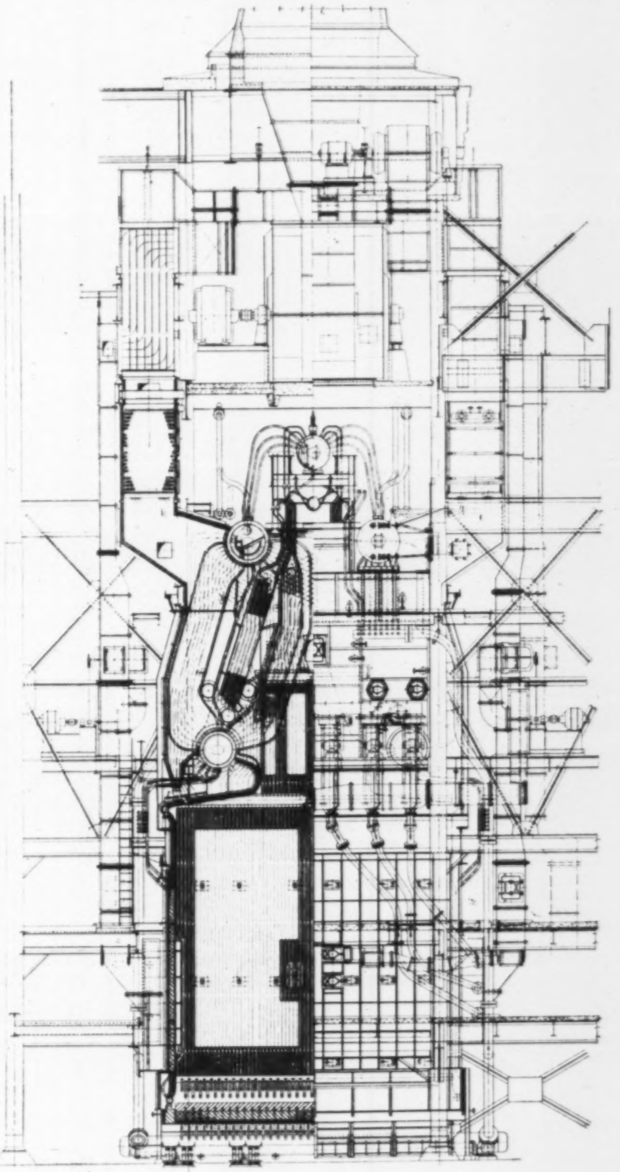

FIG. 7 COMBUSTION ENGINEERING CO.'S 5-DRUM BENT-TUBE STEAM GENERATOR FOR RIVER ROUGE STATION, FORD MOTOR CO., DETROIT, MICH.
(See Table 3 for details.)

TABLE 2 PERFORMANCE DATA OF CERTAIN AMERICAN POWER

1	Name	River Rouge	Firestone (high-pressure)	Port Washington
2	Owner	Ford Motor Co.	Firestone Tire & Rubber Company	The Milwaukee, Elec. Railway and Light Co.
3	Location	Dearborn, Mich.	Akron, O.	Port Washington, Wis.
4	Operating press., lb per sq in. gage; operating temp, F	5 boilers, 2 boilers, 1 boiler,[c] 250-650 1,250-750 1,250-900	1,250-750	1,230-825
5	Total installed capacity, kw	325,000	10,000	80,000 (noml) 85,000 (max)
6	Unit capacity of turbines, kw, rpm	#1-2-3 30,000-1,200 #4 & 5 110,000-1,800 #6 15,000-3,600[d]	10,000-3600[d]	80,000-1800
7	Spinning reserve carried on system?	No	No	Yes
8	Type and size steam-reheater surface, sq ft	#4 turbine—2 steam reheaters 8,150 sq ft each	None	Radiant reheater, 1,420 sq ft on rear wall of furnace
9	No. extraction heaters	#4 & #5 turbines—4	None	5
10	Final temp feed, full load, F	407 on h-p plant 240 on l-p plant	375	427
11	Total no. boilers	8 (7 in operation)	One	One
12	Boiler surface per unit, sq ft	1 boiler, 4 boilers, 2 boilers, 1 boiler, 250 lb 250 lb 1,250-750 1,250-900 26,470 29,494 37,274 39,500	17,680	44,087 exclusive of waterwalls
13	Economizer surface per boiler unit, sq ft	None None 14,000 25,300	8,110	None
14	Air-preheater surface per boiler unit sq ft	None 39,700 64,800 88,016	23,100	2—plate-type, total = 121,000
15	Max steam-generator output per boiler unit, lb per hr	200,000 500,000 750,000 900,000	350,000	690,000
16	Average boiler-plant eff per unit, per cent	82.5 83.7 87.5 ……[c]	85	84.9 (5 months)
17	Furnace equipment	Pulverized coal, fin-type waterwalls; tangential firing on h-p units; dry bottom	Water-tube walls and bottom	Waterwalls, dry hopper bottom, low heat release
18	Ash-handling equipment	Ash-screw, vacuum system	Slag-tap bottom, A.S.H. hydrojet disposal	A.S.H. sluicing conveyor
19	Condenser surface per unit, sq ft	Turbines #1-2-3 #4 #5 48,000 77,000 73,000	None	52,500
20	Max cooling-water temp, F	78		75
21	Min cooling-water temp, F	32		35
22	Gross annual output, kwhr	l-p plant h-p plant 136,229,971 492,288,000	51,342,000	185,515,000[e]
23	Auxiliary use, kwhr	7,210,000 21,120,000	2,795,228	10,159,431[e]
24	Net annual output, kwhr	129,019,971 471,168,000	48,546,772	175,355,569[e]
25	Auxiliary use, per cent	5.29 4.29	5.45	5.48
26	Avg cost coal per ton (2,000 lb)		$2.80	$3.82
27	Heating value coal, Btu per lb	14,150	12,300	12,999
28	Average annual station performance (net output), Btu per kwhr	l-p plant, h-p plant, 16,570 12,250	32,400[d]	11,166[e]
29	Annual load factor,[a] per cent	49.5	Base-load unit operates at capacity	61[e]
30	Annual use or capacity factor,[b] per cent	35.8	58.5	53[e]

NOTE: Pressures in lb per sq in. gage. Boiler efficiencies based on higher heating values of fuel. A.S.H. = Allen, Sherman, Hoff Company.

[a] *Annual load factor* = The ratio of the gross annual output in kwhr to the product of the maximum peak load of the year and the total hours of operation per year.

[b] *Annual use or capacity factor* = The ratio of the gross annual output in kwhr to the product of the rated capacities of the units in the station and the hours of the year (8760).

[c] Under construction.

[d] Noncondensing.

[e] This station had only been in operation for 6 months when data were compiled.

[f] The high-pressure equipment was superposed upon an older low-pressure plant.

[g] The figures given under these items are for the entire plant including both the old l-p (220-lb) section and the new rebuilt section.

[i] Corrected for steam used for heating feedwater in l-p (225-lb) section of station.

[j] Relay capacity supplied by less efficient station and by interconnection with another utility.

[k] This station is the first 1200-lb superposed station. It was originally planned for 365-lb operation and at present operates at low capacity factor in parallel with neighboring hydroelectric system. The stand-by fuel plus operation of low-pressure boilers influence performance.

[l] To extent of capacity of largest unit on line.

[m] Not operated in 1935.

[n] This station carries peak loads with base load supplied by hydroelectric power from Niagara Falls.

[o] This station is a stand-by to a large hydroelectric system.

tion tubes to provide sufficient circulating head with proper flow areas in connections. It has also been proposed to place the straight tubes at a greater angle than in previous practice.

The first installations at 1200–1400 lb per sq in. were provided with forged-steel drums. In some cases, the drums are forge-welded and the separately forged heads are fusion-welded on to the drum. In other cases, the drum is formed of bent plate and fusion-welded throughout by the metal-arc process. Welded construction has materially reduced the cost of drums. Both plain-carbon and carbon-molybdenum steels are used in drums. A.S.M.E. codes govern this construction. Drums as large as 60 in. in diameter for a pressure of 1400 lb per sq in. and $4^3/_4$ in. thick for Waterside station of the New York Edison Co., Fig. 6, will be welded. Many data upon the stresses in drum and tubes, and other design information, are given in a recent paper by Perry Cassidy (14). The main welded joints are inspected by radiographic methods, and the completely welded drums are subjected to a thermal stress-relieving treatment. The magnaflux method is frequently used to detect cracks in welds. The advantages of welding are higher joint efficiency, elimination of leaky rivets, and comparative freedom from caustic embrittlement. Fusion welding is used for the attachment of structural support lugs, baffles, and other parts.

One of the problems of these high-pressure boilers is the provision of accurate water-level indicating instruments. Differences in temperature and density make the indications of the usual gage glass and water column uncertain. Gage glasses are hard to maintain under these conditions. Various new water-level indicators are being developed.

Where extensive water-wall areas are provided in which the rate of evaporation is high, there may be a large shrinkage of water level in the drum should the load be suddenly removed, the fire practically extinguished, and the boiling in water walls cease. The swelling of water in the drum from sudden increase in load from no-load condition is an even more serious condi-

STATIONS FOR THE PERIOD JANUARY 1, 1935, TO DECEMBER 31, 1935

Northeast	Buzzard Point	Conner's Creek (rebuilt section)	Burlington	1
Kansas City Power & Light Co.	Potomac Electric Power Co.	Detroit Edison Co.	Public Service Elec. & Gas Co. of N. J.	2
Kansas City, Mo.	Washington, D. C.	Detroit, Mich.	Burlington, N. J.	3
l-p plant, 275-700 h-p plant,^{f} 1,300-725	675-845	600-850	645-846 (h-p unit)^{f}	4
139,000	35,000	90,000	60,000 kva	5
1—10,000-3,600 h-p unit^{d} 3—23,000-1,800-275 lb 2—30,000-1,800-275 lb	35,000-1,800	3—30,000-1,800	1 h-p—22,500 kva-3,600^{d} 3 l-p—12,500 kva-1,800	6
Yes	Yes	Yes	None	7
Each h-p boiler contains a 967 sq ft radiant reheater	None	None	None	8
2 on l-p turbines	3	4	3 and evaporator	9
215	350	388	366	10
2—1400 lb per sq in. 12— 300 lb per sq in.	two (one for future unit)	4	1—h-p boiler	11
8 boilers, 300 lb, 13,512 · 2 boilers, 300 lb, 12,740 · 2 boilers, 300 lb, 12,740 · 2 boilers, 1,400 lb, 16,950	5,805	26,792	43,756	12
14,000 · 10,037 · 8,100 · 10,891	11,067	8,490	None	13
...... · 9,600 · 9,600 · 39,270	45,994	28,980	41,800	14
125,000 · 125,000 · 125,000 · 250,000	375,000	420,000	600,000	15
80.6 (composite average all boilers) 85.4 on h-p boilers	84.1	87.5	84	16
h-p boilers with water-cooled furnaces and pulverized-coal fired; also 1 l-p boiler; l-p boilers, stoker-fired, chain-grate	Bailey stud-tubed refractory-covered slag bottom	Underfeed stokers, complete waterwalls	8 Enco oil burners, 8 Lopulco pulverized-coal burners	17
Water-sealed ashpits, grab bucket	Hydraulic sluicing, Cottrell precipitator	Conventional stoker ash hopper	A.S.H. hydrojet disposal	18
3—23,000 kw, 35,000 · 1—30,000 kw, 40,000 · 1—30,000 kw, 45,000	30,000	27,000	h-p—noncondensing l-p—16,000 each	19
86	84 (monthly avg)	78	82	20
32	39 (monthly avg)	32	35	21
464,855,000	222,886,000	461,250,300^{g}	305,615,000	22
29,456,579	11,740,900	19,983,000^{g}	17,082,236	23
435,398,421	211,145,100	441,267,300^{g}	288,532,764	24
6.33	5.27	4.33	5.59	25
\$2.394	\$4.51	\$3.68^{g}	\$4.70 (oil—\$0.80 per bbl)	26
10,349	14,193	13,350^{g}	14,118 (Oil—18,164)	27
14,920	12,550	13,000^{g}	15,257 (l-p section alone—29,559)	28
48.3	62.8	24.6^{g}	62	29
38.7	72.6	Rebuilt section only 69.4 Old l-p section 2.5 Combined^{g} 32.3	58	30

tion. Some plants are therefore provided with extra boiler-drum capacity. Others have feed regulators designed to vary water level proportionately to load to provide for swelling and shrinkage. This problem will be more pressing as greater relative areas of evaporating surface are placed in waterwalls and slag screens. Large drums provide more steam-liberating surface and permit the installation of better interior baffles and steam washers.

The availability of boilers has been increased by greater attention to good circulation, treatment of boiler feedwater, and control of furnace conditions to prevent slagging of the tubes. M. K. Drewry in a recent paper (15) states that four large 1400 lb per sq in. boilers during five years had an average availability factor of 94.5 per cent. Since the first boiler installed is subject to ash accumulations the average availability factor of the three later boilers exceeds 94.5 per cent. This justifies the use of such steam generators in the one-boiler one-turbine unit system.

STEAM WASHERS

"Carry-over" of dissolved solids in the water droplets with the steam leaving the boiler drum may result in deposits of these solids on the blading of high-pressure turbines, which reduce their capacity. Such blade deposits can only be removed by washing. In operation this entails a troublesome process of desuperheating the steam to the turbine while revolving slowly and dissolving the deposits with wet steam. Stoppage of superheater tubes has also been traced to carry-over. The amounts carried over may be large with high alkalinities and large sulphate contents in the boiler water.

Steam scrubbers or washers of various designs have been placed in the boiler drum. These scrubbers use the incoming feedwater to "wash" the outgoing steam, which is then freed of moisture. The quantity of solids carried over by the steam to the superheater has been reduced to comparatively small amounts by these devices.

SUPERHEATERS

Up to about 850 F carbon-steel tubes are used in superheaters. Above this temperature alloy tubes of chrome-nickel or chrome-molybdenum steels have been employed.

Superheater design is dependent upon location, method of heat absorption, and gas temperatures. Superheater surface may be radiant, convection, or combinations of these. A major objective in modern design is constancy of superheat over the range of load. This may be secured by combined radiant and convection surfaces, by intermediate desuperheaters for all or a portion of the steam, or by damper control whereby some of the gases can be bypassed around a portion or all of the superheater surface, or can be caused to flow in greater volume over portions of this surface. Damper control appears to be increasing in use. Several of these arrangements of superheaters are shown on Figs. 4, 6, 9, 10, and 11. Konejung discusses various methods of regulating superheat temperatures in a recent article (16). Dust and slag must be removed from tubes to maintain superheat. Some superheaters are designed so that all portions can be drained.

The arrangement of the boiler surface between the furnace and the superheater must provide gases to the superheater which are sufficiently hot to give the desired steam temperature at the

TABLE 2 PERFORMANCE DATA OF CERTAIN AMERICAN POWER

1	Name	Riverside (450-lb section)	Hudson Ave				
2	Owner	Northern States Power Co.	Brooklyn Edison Co				
3	Location	Minneapolis, Minn	Brooklyn, N. Y				
4	Operating press., lb per sq in. gage; operating temp, F	417–738	400–730				
5	Total installed capacity, kw	35,000	770,000				
6	Unit capacity of turbines, kw, rpm	35,000-1,800	#1-2-3— 50,000-1,200 #4 — 80,000-1,800 #5-6 —110,000-1,800 #7-8 —165,000-1,800				
7	Spinning reserve carried on system?	Yes	Yes[f]				
8	Type and size steam-reheater surface, sq ft	None	None				
9	No. extraction heaters	3 on 35,000-kw unit and 1 in l-p (225-lb) section	2 per unit except #4 which has 4				
10	Final temp feed, full load, F	303	#1-2-3—300; #4—380 #5-6-7-8—275				
11	Total no. boilers	3	32 (4 per turbine)				
12	Boiler surface per unit, sq ft	17,740 + 1,330 in waterwall	Turbines #1-2-3 12 boilers 19,650	Turbine #4 4 boilers 22,920	Turbine #5 4 boilers 23,760	Turbine #6 4 boilers 24,700	Turbines #7-8 8 boilers 24,450
13	Economizer surface per boiler unit, sq ft	12,096			14,960	21,420	22,400
14	Air-preheater surface per boiler unit, sq ft	None		43,290			
15	Max steam-generator output per boiler unit, lb per hr	750,000	145,000	235,000	312,000	312,000	452,000
16	Average boiler-plant eff per unit, per cent	83.89	[m]	[m]	86.8	87.3	86.7
17	Furnace equipment	Underfeed stoker, waterwalls	Refractory wall	Bare-tube water-wall	Block-covered water-wall	Block-covered water-wall	Fin-tube water-wall
18	Ash-handling equipment	A. S. H. ash-sluicing	Sluice only		Individual hoppers and sluice		
19	Condenser surface per unit, sq ft	29,000	70,000	80,000	85,000	88,500	101,000
20	Max cooling-water temp, F	88.5	31				
21	Min cooling-water temp, F	32	31				
22	Gross annual output, kwhr	192,077,000	2,057,548,000				
23	Auxiliary use, kwhr	5,020,000	83,910,000				
24	Net annual output, kwhr	187,057,000	1,973,638,000				
25	Auxiliary use, per cent	2.6	4.08				
26	Avg cost coal per ton (2,000 lb)		$4.862				
27	Heating value coal, Btu per lb	13,833	13,990				
28	Average annual station performance (net output), Btu per kwhr	13,526[i]	13,500				
29	Annual load factor,[a] per cent	69.7	46.9				
30	Annual use or capacity factor,[b] per cent	62.6	30.4				

NOTE: Footnotes to Table 2 are given on page 548.

various outputs. Supports for superheater tubes are difficult to maintain, particularly when exposed to radiant heat.

A frequent difficulty in superheaters which is troublesome to correct is a lack of equal distribution of steam to all the tubes. Superheater tubes often leak where rolled into headers. This may be due to the partial annealing of the cold-worked metal of the rolled sections by the high-temperature steam, or to differences in the coefficients of heat expansion of tube and header which may be corrected by diminishing the temperature differences of the two materials. Welding is considered for these connections. The overheating of superheater tubes during starting-up periods may present a problem due to lack of steam flow through the superheater. In some installations, dampers bypass the hot gases around the superheater when starting up, as in Figs. 9 and 10.

BOILER FEEDWATER

Much attention is given to the proper conditioning of feedwater for high-pressure boilers, and feedwater requirements are often specified by the boiler manufacturer. In central stations where condensate is returned to the boilers, make-up has been reduced to a small amount, often less than 1.5 per cent, and is supplied by evaporators fitted into the system heat balance. The reserve storage of distilled water frequently amounts to 2 gal per kw of capacity.

In industrial plants where make-up is large, boiler feedwater is given a chemical treatment before entering the boilers. This may consist of a hot lime-soda softener, a Permutit softener, or some other treatment. Several of these processes replace the soluble lime salts by soluble soda salts in the feedwater. Where these soda salts unduly increase boiler concentration, chemical methods of treatment are being developed to lessen total solids entering the boiler. Colloidal treatments are also used in some cases.

A prime essential is the reduction of dissolved oxygen in the feedwater practically to zero by the Winkler test. While the condenser itself serves to remove oxygen in some plants, deaerators in the feed system are widely used. It is quite general practice to add sodium sulphite to the feedwater as it enters the boiler to remove the last traces of oxygen and thereby eliminate corrosion. Removable detector rods and disks have been used to indicate corrosion.

Corrosion difficulties are also reduced by maintaining a high alkalinity of the water in the boiler drum. This degree of alkalinity varies over a considerable range of pH values depending upon local conditions. A pH of at least 9.6 is considered necessary by many, while in some cases this may be as high as 11.0, particularly with high silicates present. High alkalinity requires at high boiler pressures a large amount of sodium sulphate to maintain the A.S.M.E. sulphate-alkalinity ratio to inhibit caustic embrittlement. Sodium phosphate is used at times to reduce the quantity of sulphate necessary, to control residual hardness from condenser leakage, and to lessen boiler-water concentration.

STATIONS FOR THE PERIOD JANUARY 1, 1935, TO DECEMBER 31, 1935 *(Continued)*

Charles Leavitt Edgar				C. R. Huntley No. 2[n]	Station A	1
The Edison Electric Illuminating Company of Boston				Buffalo General Electric Co.	Pacific Gas & Electric Co.	2
Fore River, North Weymouth, Mass				Tonawanda, N. Y	San Francisco, Calif	3
3 boilers—365-715 1 boiler—1,150-700, reheat at 365-715 4 boilers—1,325-725, reheat at 365-750				425-750	1,250-750 750 reheat	4
Main generators—157,860 Auxiliary generators—9,000 Total turbines—166,860				160,000	100,000	5
2—38,000-1,800 for 350 lb per sq in., 700 F 1—65,000-1,800 for 350 lb per sq in., 750 F 1— 3,360-3,600 for 1,060 lb per sq in., 685 F 1—10,000-3,600 for 1,200 lb per sq in., 710 F 1—12,500-3,600 for 1,200 lb per sq in., 710 F				80,000-1800	50,000—h-p—3,600 l-p—1,800	6
No[i]				Yes	No	7
3 reheat boilers: For 1,150-lb boiler, reheater = 5,938 For two 1325-lb boilers, reheater = 6,936 For two 1325-lb boilers, reheater = 5,596				None	2 reheat boilers; steam reheater = 2,684; flue-gas reheater = 9,560	8
38,000-kw turbines—2 65,000-kw turbine—3				4 per turbine plus evaporator condenser	4 per turbine	9
From 38,000-kw turbines—240 From 65,000-kw turbine —310				357	425	10
8				4	2 reheat, 1 standard	11
3 boilers 365-715 19,743	1 boiler 1,150-700 15,631	2 boilers 1,325-725 15,093 + 1,206 waterwall	2 boilers 1,325-725 6,971 + 1,206 waterwall	36,792	10,699	12
11,100	11,100	5,596	9,634		Reheat boilers = 17,900 Standard boilers = 21,111	13
None	None	33,032	29,665	90,000	Reheat boilers = 51,606 Standard boilers = 46,915	14
150,000	142,000	225,000	250,000	560,000	500,000	15
83	83	86	86	87	No data	16
Refractory wall Taylor stoker	Refractory walls Taylor stoker	Refractory front wall and waterwalls	Refractory front wall and waterwalls	Bailey waterwalls 6 cross-tube burners per boiler	Bailey waterwalls, combination natural gas and mechanical fuel-oil burners	17
Double-roll, clinker grinders, ash hoppers and trucks	Double-roll, clinker grinder, ash hopper and trucks	Taylor stoker, double-roll, clinker grinder, ash hopper	Taylor stoker, double-roll, clinker grinder	Slag-tap A. S. H. sluicing	None	18
38,000-kw turbines—45,000 (each) 65,000-kw turbine—50,000			Ash hopper and trucks	45,000	34,000	19
68				75	63	20
32				32	50	21
628,075,000				299,327,300	102,257,000[o]	22
41,325,922				22,070,600	23,106,109[o]	23
586,749,078				277,256,700	78,150,891[o]	24
6.58				7.37	23.57[o]	25
$4.851				$3.10	Gas and oil used	26
14,083				13,185	Gas—1,180 Btu per cu ft Oil—18,500 Btu per lb	27
14,069[k]				15,080	19,700[o]	28
53.8				20.9	15.6[o]	29
23.1				21.3	11.7[o]	30

Total solids permissible in boiler water have to be determined at each plant. This quantity is dependent upon water conditions, water treatment, and the steam disengaging area in boiler drums. Large drums are desirable to reduce foaming difficulties.

Feedwater treatments are still undergoing development and new methods are being tried. The recent discovery that silica is largely responsible for caustic embrittlement may lead to extensive modifications of water treatment.

ECONOMIZERS

Economizers to heat the feedwater with flue gases are used quite generally. New forms of continuously welded economizer tubes, some with extended fin surfaces, have been developed in which steam may be generated at certain loads forming so-called "steaming economizers." The feedwater to economizers is generally heated above 220 F by extracted steam from the main turbines. Hence external condensation and corrosion are no longer serious difficulties. Economizers are shown in Figs. 4, 6, 7, 8, 9, 10, 11, and 12.

AIR PREHEATERS

Air preheat for stokers has generally been limited to about 300 F, but stokers have been operated with air at 500 F. Higher temperatures up to 600 F are used with pulverized coal. Much higher temperatures could be used with the latter, but metals in air preheaters oxide rapidly at the higher temperatures. Various air-heater arrangements are shown in Figs. 3 to 12, inclusive.

Difficulties have been experienced with plugging of portions of air preheaters with flue dust. In general this is due to metal temperatures, at the cold end and at points where circulation is poor, falling below the dew point of the gases, which leads to condensation, corrosion, and dust deposits on such surfaces. The trouble can be corrected by maintaining uniform distribution of gases and air and by recirculating a portion of the preheated air to prevent condensation. At Lakeside station, Milwaukee, Wis., sufficient air is recirculated to maintain minimum metal temperatures in the preheaters of 210 F. No troubles have been experienced with condensation on these heaters in five years' service. In some cases, wear of preheater plates has been severe from cinders of stoker furnaces.

The air preheater has been placed behind the boilers in a recently built station to reduce boiler-room height. This heater has tubes through which the gases pass and which slope slightly downward from the gas inlet.

WATERWALLS

Waterwalls of many types are in use and, as shown in Table 3, are installed in all new plants. Some walls consist of bare tubes placed side by side. Others have fin tubes with narrower and shorter fin sections than in earlier installations. Still others have cast-iron block covering, smooth or refractory faced. One builder welds small studs to the tubes, which are covered with refractory material, as in Figs. 8, 9, 10, and 11.

TABLE 3 DATA ON RECENT STEAM

1	Name	Port Washington	River Rouge	Hudson Avenue Boilers for units 7 & 8	Buzzard Point
2	Owner	The Milwaukee Elec. Railway & Light Co.	Ford Motor Co.	Brooklyn Edison Co.	Potomac Elec. Pr. Co.
3	Location	Port Washington, Wis.	Dearborn, Mich.	Brooklyn, N. Y.	Washington, D. C.
4	Date of installation	1935	1936	1932	1933
5	Builder of boilers[a]	C.E. Co.	C.E. Co.	C.E. Co.	B. & W. Co.
	a Type of boiler	Bent-tube with reheater	5-drum bent-tube	Bent-tube. Ladd-type with mud drum, two upper drums and dry-drum	Water-tube, cross-drum, high-head, single-pass
6	Operating press., lb per sq in., gage	1,320	1,250	410	750
7	Steam temp, F	825	900	730	845
8	Type of firing equipment	C. E. Co. bin-and-feeder system, pulverized-coal, vertical burners	C.E. Co. Lopulco tangential-firing, pulverized-coal	Taylor underfeed stokers	Atrita pulverizers, direct-firing, pulverized-coal
9	Furnace volume, cu ft	Combustion space = 58,000 Total volume = 72,000	29,000	14,000	12,006
10	Maximum rating, steam, lb per hr	690,000	900,000	530,000 (two hours) 452,000 (continuous)	375,000
11	Feedwater temp[b] (max rating), F	427	395	275	350
12	Heating surfaces, sq ft				
	a Boiler proper	47,087	30,000	24,450	5,805
	b Waterwalls and bottom	7,976	9,500	3,846	3,917
	c Superheater	8,891 convection 1,464 side walls 1,420 rear wall	14,150 convection 6,900 radiant	5,740	6,693
	d Economizer	None	25,300	22,400	11,067
13	Type and capacity of air preheater (or sq ft of heating surface)	Two plate heaters, total = 121,000	Plate heater 86,016	None	Inclined-tubular; flue gases flow through tubes, 45,994
14	Heat release in furnace, Btu per cu ft per hr				
	a Below water screen				51,200
	b Total furnace volume	15,000 max based on 58,000 cu ft	39,000	45,000 (max continuous)	36,800
15	Type of drum	Forged from single billet and machined	Forged drums with welded heads	Riveted	Fusion-welded
16	Type of furnace bottom	Dry hopper bottom	Dry bottom with ash screw	Stoker-fired	Water-cooled bare cast-iron block, slag-bottom

1	Name	Monsanto	Holyoke	Springdale	Lynn
2	Owner	Monsanto Chemical Co.	Holyoke Water Power Co.	West Penn Power Co.	Lynn Gas & Elec. Co.
3	Location	St. Louis, Mo.	Holyoke, Mass.	Springdale, Pa.	Lynn, Mass.
4	Date of installation	1935	1936	Under construction	1936
5	Builder of boilers[a]	B. & W. Co.	Riley Stoker Corp.	B. & W. Co.	Riley Stoker Corp.
	a Type of boiler	Stirling	Ring-flow, bent-tube	Single-pass, high-head, cross-drum	Ring flow, bent-tube
6	Operating press., lb per sq in., gage	675	675	1,270	430
7	Steam temp, F	770	750	935	810
8	Type of firing equipment	Stoker, chain-grate	Oil or pul.-coal	Pul.-coal	Pul.-coal
9	Furnace volume, cu ft	2,700	8,800	16,130	11,700
10	Maximum rating, steam, lb per hr	80,000	170,000	575,000	205,000
11	Feedwater temp[b] (max rating), F	325	350	425	275
12	Heating surfaces, sq ft				
	a Boiler proper	7,562	10,500	6,369	14,800
	b Waterwalls and bottom	734	5,700	5,286	5,660
	c Superheater	2,614	2,450	19,070	4,830
	d Economizer	1,140	None	16,700	None
13	Type and capacity of air preheater (or sq ft of heating surface)	Tubular, 3,520	Tubular, 15,600	Tubular, 32,700	Ljungstrom
14	Heat release in furnace, Btu per cu ft per hr				
	a Below water screen				
	b Total furnace volume	33,400	25,000	44,600	24,200
15	Type of drum	Fusion-welded	Fusion-welded	Fusion-welded	Fusion-welded
16	Type of furnace bottom	Stoker	Dry, water-cooled hopper	Slag-tap, continuous tapping	Dry, water-cooled hopper

1	Name	East Windsor	Waterside	Omaha	12th Street
2	Owner	Ford Motor Co. of Canada	New York Edison Co.	Nebraska Power Co.	Virginia Electric & Power Co.
3	Location	East Windsor, Ont.	New York, N. Y.	Omaha, Neb.	Richmond, Va.
4	Date of installation	Under construction	Under construction	Under construction	Under construction
5	Builder of boilers[a]	C.E. Co.	C.E. Co.	C.E. Co.	C.E. Co.
	a Type of boiler	3-drum, bent-tube	Cross-drum, sectional header	3-drum, bent-tube	3-drum plus 1 dry-drum, bent-tube
6	Operating press., lb per sq in., gage	850	1,325	1,225	860
7	Steam temp, F	820	900	915	835
8	Type of firing equipment	Pul.-coal, storage system, tangential-firing	Pul.-coal, direct system, tangential-firing	Green, forced-draft, chain-grate stoker	Pul.-coal, direct system, tangential-firing
9	Furnace volume, cu ft	8,300	20,300	10,800	19,400
10	Maximum rating, steam, lb per hr	200,000	500,000	275,000	450,000
11	Feedwater temp[b] (max rating), F	325	375	380	375
12	Heating surfaces, sq ft				
	a Boiler proper	9,010	7,000	12,000	24,930
	b Waterwalls and bottom	4,300	4,800	3,063	11,060
	c Superheater	7,125 convection 3,495 semiradiant	14,000	9,720	8,650
	d Economizer	4,220	18,850	18,130	None
13	Type and capacity of air preheater (or sq ft of heating surface)	Plate, 9,940	Ljungstrom, 65,400	12,250	Ljungstrom, 32,200
14	Heat release in furnace, Btu per cu ft per hr				
	a Below water screen				
	b Total furnace volume	31,400	31,000	34,000	29,300
15	Type of drum	Fusion-welded	Fusion-welded	Fusion-welded	Fusion-welded
16	Type of furnace bottom	Dry hopper bottom	Slagging	Ash-hopper	Slagging

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[a] C.E. Co. = Combustion Engineering Company; B. & W. Co. = Babcock & Wilcox Company.

[b] Entering economizer, if used.

[c] Replaces existing low-pressure units, but not superimposed.

GENERATING INSTALLATIONS

Steel Works	Conner's Creek (rebuilt section)	Huntley No. 2	Firestone	Burlington
Weirton Steel Co.	Detroit Edison Co.	Buffalo Gen. Elec. Co.	Firestone Tire and Rubber Co.	Public Service Elec. & Gas Co. of N. J.
Weirton, W. Va.	Detroit, Mich.	Tonawanda, N. Y.	Akron, O.	Burlington, N. J.
1936	1934–1935	1930	1934	1932
B. & W. Co.	C.E. Co.	B. & W. Co.	C.E. Co.	C.E. Co.
Stirling	Bent-tube, Type VV	Horizontal cross-drum, straight-tube	Hedges, Walsh & Weidner's cross-drum	Walsh & Weidner, cross-drum, straight-tube
850	650	450	1,300	700
841	850	765	750	860
Pulverized-coal	Multiple-retort, Taylor underfeed stokers	2—15-ton table pulverizers. Unit system. 6 cross-tube burners	Lupulco tangenital-firing. Pulverized-coal. 4—6 in. duplex feeders	Coal—4 Lupulco type-R horizontal pul.-coal burners. Oil—8 Enco mechanical atomizing burners
17,280	11,000	22,900	14,500	25,880
400,000	420,000	560,000	350,000	600,000
250	388	357	370	370
20,487	26,792	36,972	11,793	29,740
4,277	2,478	3,301	5,887	4,816
9,230	9,429	9,350	4,000	9,200
None	8,490	None	8,110	None
Tubular 49,500	Plate-type cross counter-flow 28,980	Regenerative 90,000	Plate 23,100	Vertical plate, 41,800
				28,820
31,000	50,400	32,000	14,500	20,090
Fusion-welded	Fusion-welded	Riveted	Fusion-welded	Riveted
Water-cooled covered slag bottom	Stoker-fired	Both air- and water-cooled, slag-bottom	Water-cooled, slag-bottom	Water screen, Dry-bottom

West End	Richmond	Miller's Ford	Station No. 3	Logan	Northeast
Union Gas & Elec. Co.	Standard Oil of California	Dayton Power & Light Co.	Rochester Gas & Electric Company	Appalachian Electric Power Co.	Kansas City Power & Light Co.
Cincinnati, O.	Richmond, Calif.	Dayton, O.	Rochester, N. Y.	Logan, W. Va.	Kansas City, Mo.
Under construction	1936	1936	1935	Under construction	Under construction
B. & W. Co.	Riley Stoker Corp.	B. & W. Co.	C.E. Co.	C.E. Co.	C.E. Co.
Open-pass, 4-drum	Ring-flow, bent-tube	Single-pass, high-head, cross-drum	4-drum, bent-tube, with fifth washer drum	Special 6-drum double-set, bent-tube	Cross-drum, sectional header
1,275	850	1,250	660	1,325	1,275
925	760	900	755	925	815
Pul.-coal	Oil, gas, and acid sludge	Pul.-coal	Pul.-coal, 2-unit mills	Pul.-coal, direct-fired, tangential-firing	Pul.-coal, direct-fired, tangential-firing
4,750	6,700	12,100	15,220	41,000	15,000
350,000	125,000	375,000	250,000	1,000,000	300,000
350	350	385	388	430	215
22,788	9,600	3,367	15,300	20,800	3,500
1,878	2,100	2,781	3,630	12,260	3,970
7,357	1,840	10,460	10,613	24,720	5,170
15,191	None	21,000	20,808	25,808	Reheater = 5,700 10,000
Tubular, 34,800	Tubular, 12,000	Tubular, 26,720	Steam aerofin (air to mills only), 1,921	Ljungstrom, 90,400	Ljungstrom, 36,800
82,100 48,000 at 300,000 lb steam	25,000	39,200	21,800	29,800	30,900
Fusion-welded	Fusion-welded	Fusion-welded	Fusion-welded	Fusion-welded	Fusion-welded
Slag-tap, intermittent tapping	Refractory	Block-covered, water-cooled, hopper-bottom	Dry-bottom, A.S.H. system	Dry hopper-bottom	Slagging bottom, continuous tapping

Titanium	Station B	Keystone	Wilshire	Provo (Outdoor Station)	Montville[c]
Titanium Pigment Co.	San Antonio Public Service Co.	Keystone Public Service Co.	Wilshire Oil Co.	Utah Power Co.	Connecticut Light & Power Co.
Sayreville, N. J.	San Antonio, Tex.	Oil City, Pa.	Santa Fe Springs, Calif.	50 miles from Salt Lake City	Montville, Connecticut
1935	1930	Under construction	1936	1936	1936
Riley Stoker Corp.	D. Connelly Boiler Co. (Foster-Wheeler)	Foster-Wheeler	Foster-Wheeler	C.E. Co.	C.E. Co.
Ring-flow, bent-tube	Straight-tube, sectional header	Two-drum, bent-tube	Three-drum	Three-drum, bent-tube	2 Three-drum, bent-tube
448	1,400	725	450	434	650
637	750			750	825
Pul.-coal, direct-firing	Natural gas and oil	Pul. coal, two Intervane burners	Oil or gas	C.E. forced-draft, chain-grate, (20′ × 20′9″)	Puverized-coal, unit bowl mills supplying horizontal burners
6,750		6,280			
125,000	215,000 19,000 lb reheater 196,000 superheater	100,000	45,000	200,000	130,000 (each)
	371	212	220		
8,000	4,990	8,850	3,610	17,800	9,140 (each)
4,290		2,438	None	2,770	4,200
1,200		1,000			2,610
None	11,800	3,960	2,016		
11,600	Plate-type, 13,900	None	None		Vertical-shaft, Ljungstrom type
24,900		21,500			
Fusion-welded	Solid-forged	Fusion-welded	Fusion-welded	Fusion-welded	Fusion-welded
Dry bottom	Dry	Water-cooled, Dry	Air-cooled, Dry		Dry-bottom

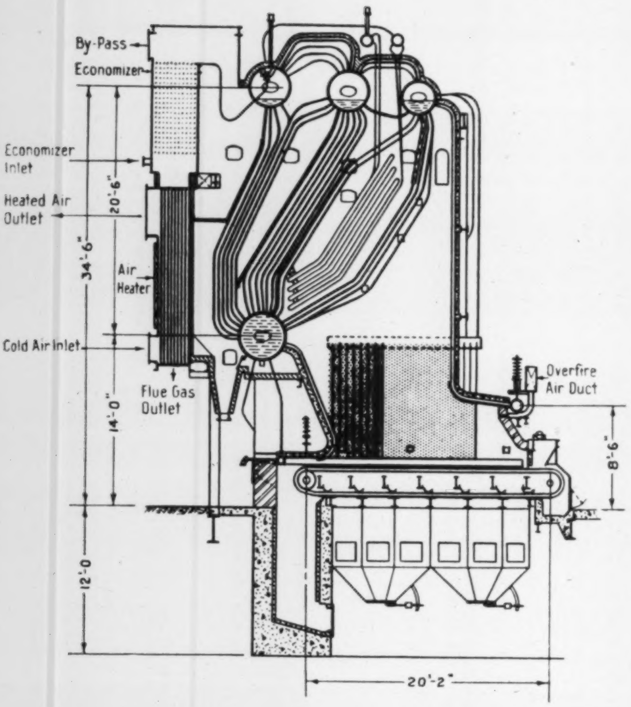

FIG. 8 BABCOCK & WILCOX CO.'S STIRLING-TYPE STEAM GENERATOR WITH CHAIN-GRATE STOKER INSTALLED AT MONSANTO CHEMICAL CO.'S PLANT

(See Table 3 for details.)

All steam generators shown from Figs. 3 to 12 have waterwalls.

With stokers, the waterwall tubes in the fuel zone are protected either by renewable cast-iron blocks, as in Fig. 4, or by blocks cast on the tubes. Waterwall sections above this zone generally have bare tubes.

No serious difficulty has developed with waterwalls, provided circulation is excellent. Heat-transfer rates vary with furnace temperatures, the degree of cleanness, and the amount of insulation provided by blocks or with studs. The effectiveness of radiant heat transfer is now generally recognized. With bare surfaces this rate of heat absorption ranges from 40,000 to 125,000 Btu per sq ft of exposed surface per hr with greater heat-transfer rates in some small units.

Waterwall construction is influenced in pulverized-coal plants by the desired state of the ash. With dry ash the furnace volume is large, rates of heat release moderately low, and furnace temperatures maintained below the fusing point of the ash by large bare waterwalls. With liquid ash, high furnace temperatures from high rates of combustion in relatively smaller furnaces are necessary and either refractory-covered walls in whole or in part, or walls of plain or fin tubes, are provided to attain these ends.

Water-cooled slag screens were first used over dry-bottom ashpits and are still so installed. Formerly, certain of the lower boiler tubes were so placed that the liquid ash particles in passing up the vertical passages between them, were cooled by radiation to solid nonadherent dust. Some recent boiler installations with slag- or wet-bottom furnaces have had refractory-covered slag screens placed directly above or across the side outlet of the furnace with a secondary furnace volume beyond the slag screen. These slag screens are intended to shield the boiler tubes proper from radiant heat, to intercept the liquid-ash particles, to allow them to agglomerate into large drops, and to permit this liquid slag to drop or run off into the liquid pool of ash in the furnace bottom. These screens also provide added turbulence for quickly completing combustion.

FURNACES

Chain-grate stokers are used to burn such fuel as lignite, noncoking high-ash bituminous coals, small sizes of anthracite, and coke breeze. Forced draft is generally used with these stokers. Fig. 8 shows a recent installation with stud-tube side walls, water-cooled arch and bridgewalls, and overfire air.

Underfeed stokers have been developed with zoned air control to different portions of the fuel bed, and this has improved both operation, capacity, and efficiency. Coal-burning rates of 75 lb per sq ft have been obtained. Silica carbide has been found better than cast iron in the extension grates. Improvements have been made in hopper agitators, ram and pusher drives, tuyère design, clinker pits, and grinders. Bridgewalls and side walls, at least above the clinker zone, are generally water-cooled. Fig. 3 shows the installation of a double-ended underfeed stoker with 12 retorts 41 thin tuyères long, having a projected area of 557 sq ft and a coal-burning capacity of 42,000 lb per hr at maximum load. As described in a recent paper (6), two pushers per retort are used, together with a system of automatic air control to the various sections of the stoker. Much study is being given to the provision of overfire air to underfeed stokers to improve combustion

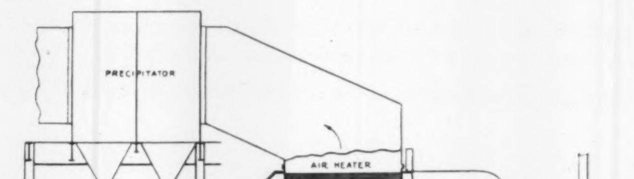

FIG. 9 BABCOCK & WILCOX CO.'S STEAM-GENERATOR UNIT ARRANGED FOR STRAIGHT-THROUGH FLOW OF GAS AND SUPERHEAT CONTROL FOR MILLERS FORD STATION, DAYTON POWER & LIGHT CO., DAYTON, O.

(See Table 3 for details.)

and prevent smoke. It is difficult to project the air sufficiently far into the furnace to provide the necessary mixing and turbulence. This overfire air has been provided by fans which force the air deeply into the furnace from both front and rear walls.

A promising development in the combustion of low-fusing-ash coal described in a recent paper (17) has been the construction and test of an underfeed stoker with water-cooled piping above the tuyères. The fluid ash solidifies before reaching the tuyères. This will enlarge the use of this type of stoker with coals which formerly could be burned only on chain-grate stokers.

No outstanding change has recently taken place in furnaces for pulverized coal with the exception of the use of slag bottoms. Since the needs of time, temperature, and turbulence were recognized, combustion conditions have generally been satisfactory. Many types of burners are available, the choice being largely fixed by desired ash conditions. Combination burners for pulverized coal with oil or natural gas are in use. Pulverizers have been improved and larger units are available. Coal is ground finer than formerly to secure better combustion conditions. Pulverizers are simple in design, respond more quickly to load changes, and have a wider range of capacity than earlier units. Recent installations have been principally direct-fired units rather than those of the bin and feeder system. Some recent furnace constructions for pulverized coal are shown in Figs. 3, 5, 7, 9, 10, and 11.

Opinions differ in regard to dry or slag-tap furnace bottoms. Apparently dry bottoms are satisfactory in furnaces of large volume with coals having ash of high fusion temperature, and with bare water-cooled walls that will maintain low furnace temperatures, as in Figs. 3, 7, and 9. On the other hand, smaller furnaces, with refractory covering on some or all portions of the waterwall to maintain high furnace temperatures and with proper slag screens, have been provided with liquid slag bottoms as in Figs. 5, 6, 10, and 11. Water-cooled bottoms seem necessary for slag-tap furnaces. Some furnaces are tapped periodically and the ash disintegrated by a water jet. In recent installations continuous tapping is provided. Continuous slag-tap furnaces are designed for ash-fusing temperatures up to 2800 F. Table 3 indicates an increasing use of slag-bottom furnaces. Slag deposits on tubes and furnace walls can be removed by a lance which discharges a jet of cold water against the hot slag.

Furances have been rated on the basis of the heat generation in Btu per cubic feet of complete furnace volume, which ranges from 15,000 to 50,000 with large boilers, with higher rates of heat release below the furnace slag-screen tubes of certain furnaces. Manufacturers now emphasize the high rates of heat release per foot of furnace width that exist in some new installations.

Automatic combustion-control equipment has been widely used in connection with automatic boiler control. It is generally applied to raw-coal feeders, forced- and induced-draft fans, and occasionally to stoker drives, and can handle large variations in load. This automatic equipment saves much labor, though it requires careful and intelligent supervision. Maintenance has not been high on these controls. It is usually necessary for the boilers to be brought on the line by hand from stand-by.

DUST REMOVAL FROM FLUE GASES

Eighteen stations use Cottrell electrostatic precipitators. Six companies use precipitators on dry-bottom pulverized-coal furnaces; two companies with slag bottoms. Precipitators are generally in two or three sections. The gas velocity through the precipitator ranges from 5 to 10 fps and the draft loss varies from 0.1 to 0.5 in. of water. Carbon in the ash decreases the recovery efficiency. Improvements are still being made in structural and electrical design, in rapping devices to remove the adherent dust, and in apparatus for dust removal from the precipitator hoppers. The efficiency of dust recovery with precipitators ranges from 90 to 95 per cent.

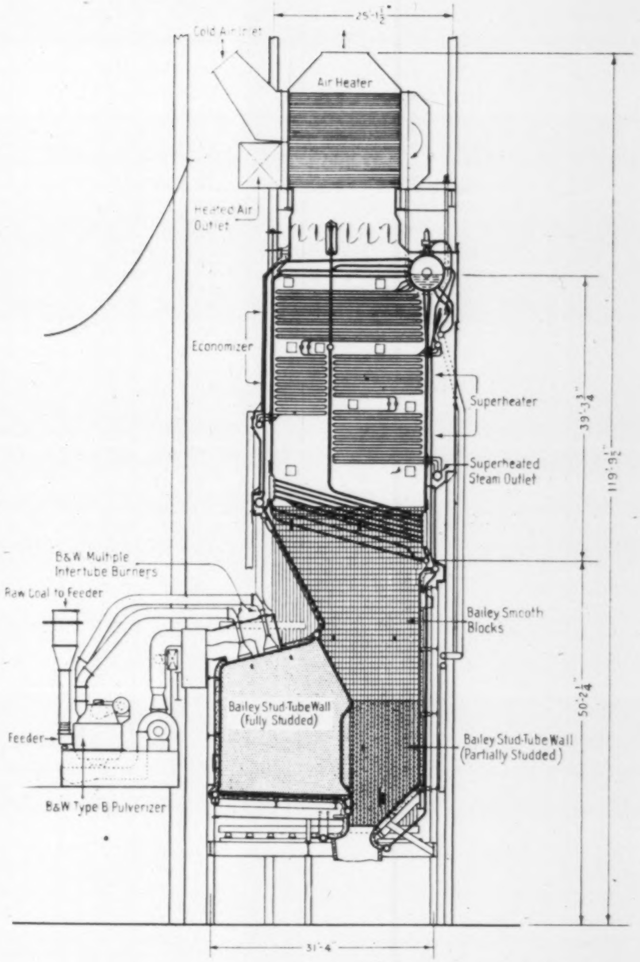

FIG. 10 BABCOCK & WILCOX CO.'S STEAM GENERATOR WITH TWO-STAGE CONTINUOUS-SLAG-TAPPING FURNACE AND WITH BOILER, ECONOMIZER, AND AIR HEATER ARRANGED FOR STRAIGHT-THROUGH GAS FLOW AND SUPERHEAT CONTROL—SPRINGDALE STATION, WEST PENN POWER CO.

(See Table 3 for details.)

Dust catchers of the cyclone type are also in use. The efficiency of these ranges from 70 to 90 per cent, with some claiming higher recovery. Film and spray washers are effective, but corrosion has been a serious problem in their maintenance. Cinder traps, dust catchers, cindervane fans, and other devices are also employed.

BOILER-AUXILIARY PLANT

Opinion is divided regarding the economic value of soot blowers. Many engineers prefer to use hand lances in place of soot blowers. The main difficulty appears to be the deterioration of soot-blower units when placed in hot zones of the boilers. Operating and maintenance costs may offset the savings from their use. A new integral form of soot blower welded to the tubes and described in a recent paper (6) has

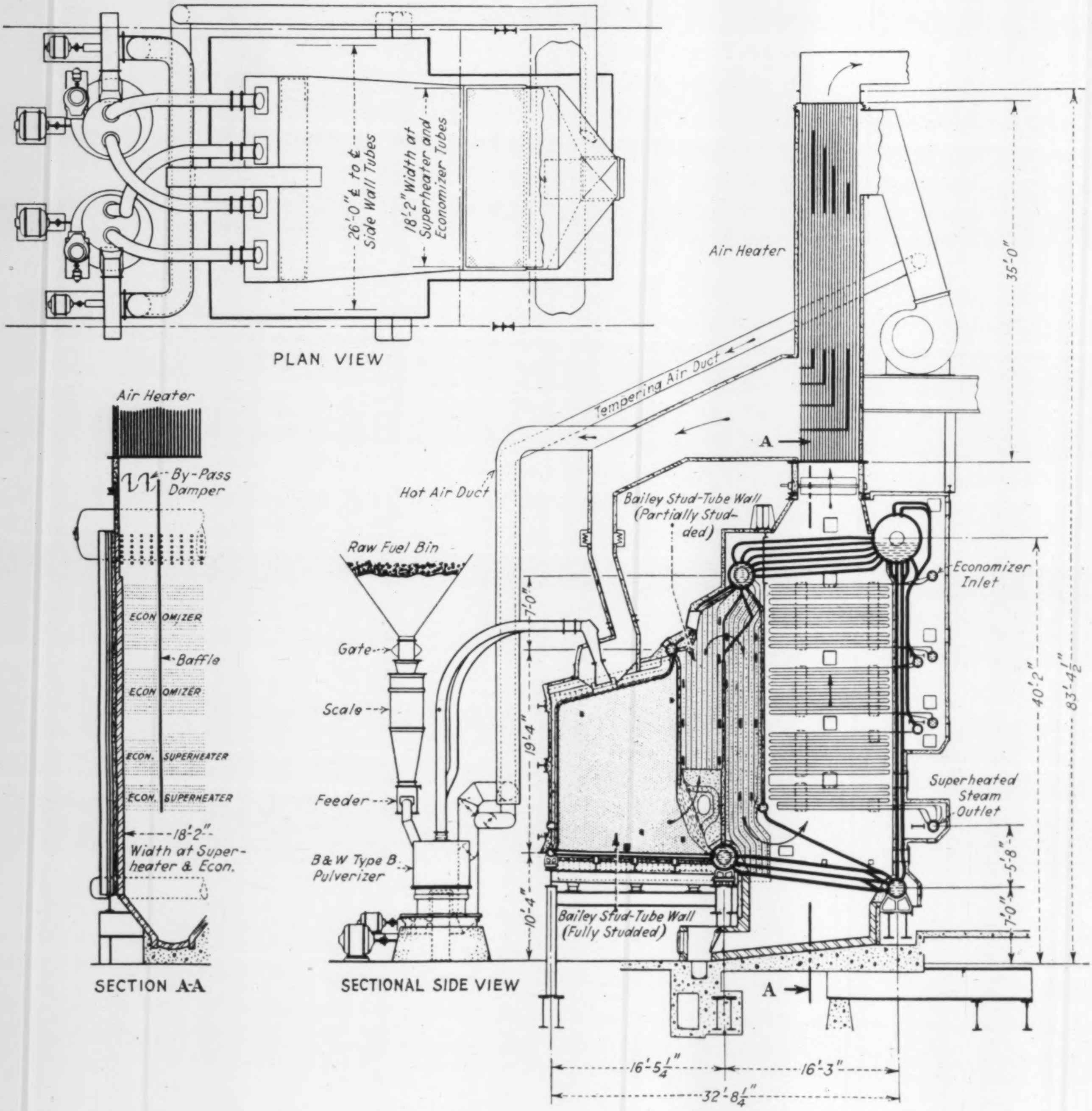
26'-0" ℄ to ℄ Side Wall Tubes
18'-2" Width at Superheater and Economizer Tubes
PLAN VIEW
Air Heater
By-Pass Damper
ECONOMIZER
Baffle
ECONOMIZER
ECON. SUPERHEATER
ECON. SUPERHEATER
18'-2" Width at Superheater & Econ.
SECTION A-A
Air Heater
35'-0"
Tempering Air Duct
A
Hot Air Duct
Bailey Stud-Tube Wall (Partially Studded)
Raw Fuel Bin
Economizer Inlet
Gate
7'-0"
Scale
19'-4"
40'-2"
83'-4½"
Feeder
Superheated Steam Outlet
B&W Type B Pulverizer
5'-8"
10'-4"
Bailey Stud-Tube Wall (Fully Studded)
7'-0"
SECTIONAL SIDE VIEW
A
16'-5¼"
16'-3"
32'-8¼"

FIG. 11 BABCOCK & WILCOX CO.'S STEAM GENERATOR WITH OPEN-PASS BOILER, SLAG-TAP FURNACE, AND SUPERHEAT CONTROL FOR WEST END STATION, UNION GAS & ELECTRIC CO., CINCINNATI, OHIO

(See Table 3 for details.)

been installed by Detroit Edison Co. at Conners Creek, and this may solve the soot-blower problem.

Wear of the blades of induced-draft fans by cinders may be offset by extensive welding. Hydraulic couplings to provide variable speed are in use with oil-pump control to give the necessary regulation of fans.

PERSONNEL OF BOILER PLANT

Nowhere in the power plant has there been a greater change in the type of operator than in the boiler room. Turbine efficiency is largely fixed by the original design, but boiler-room efficiency is only secured by constant vigilance. Hence highly trained, intelligent, alert men are needed for economical operation of this section of the plant in contrast to the strong-backed coal passers of former years. The excellent boiler-plant efficiencies of Table 2 obtained over a whole year demonstrate the abilities of these modern operators.

7—STEAM TURBINES

Few steam turbines have been built recently for central stations. Turbine builders have furnished industrial plants with many turbines of special design, such as high-back-pressure, atmospheric-exhaust, and various bleeder types, all of which provide steam for industrial use. Every industrial turbine must conform to particular local requirements and hence much engineering has been necessary in its design and construction.

The limitation in capacity of a single-cylinder single-flow condensing turbine is the amount of steam that can be economically passed through the last blade row. This capacity in kilowatts has been raised by increased heat drop, improved materials, better design, and greater use of the regenerative cycle, and present limits are merely temporary. At 3600 rpm such turbines are available at 15,000–25,000 kw capacity. Similar turbines from 80,000 to 100,000 kw capacity can be built for operation at 1800 rpm. Two-cylinder construction with double-flow low-pressure cylinders would double these capacities. The limitation of 50,000 kw at 3600 rpm is fixed by the permissible capacity of the generator. Greater use will be made of 3600-rpm units due to their small rotors and high efficiency. Fig. 13 shows a 15,000-kw, 3600-rpm condensing turbine with 19 stages, built by General Electric Co. for moderate pressures.

Back-pressure turbines are generally designed for 3600 rpm, and orders have been received for such superposed units up to 50,000 kw in capacity. One manufacturer has established a tentative limit of 2,000,000 lb of steam per hr as the capacity of this type of turbine. The main unit in the Westinghouse set of Fig. 14 consists of a Curtis element followed by 14 pairs of reaction blading. The feed-heating turbine has a Rateau wheel followed by 19 sets of reaction blades. The two connect directly to a hydrogen-cooled 58,823-kva generator, 85 per cent power factor.

The new 30,000-kw back-pressure superposed unit for Fisk St. station, Chicago, Ill., 1200 lb per sq in. gage, 900 F, exhausting at 220 lb per sq in. gage, is a 25-cycle unit operating at 1500 rpm.

The 80,000-kw Allis-Chalmers condensing turbine shown in Fig. 15 is furnished with steam at 1230 lb per sq in. gage, 825 F, which is reheated in the boiler in a radiant reheater to 825 F. The reheat pressure varies with load, its maximum being 400 lb per sq in.

Turbine rotors and casings for moderate temperatures up to 700 F have been made of carbon steels. For the higher temperatures, chrome-vanadium, chrome-molybdenum, nickel-molybdenum, carbon-molybdenum, and other alloy steels have been used. Castings are inspected by means of either X-rays or gamma rays. Blading materials consist of 12–13 per cent chromium stainless steel, and chrome-nickel steels for high temperatures and high stresses. Cylinder bolts offer difficult problems and many materials are being tried, of which chrome-molybdenum steel appears promising.

The maximum ratio of blade length to mean diameter in the last row of blades is now about 0.33. Warped blades are generally employed for this row. One manufacturer endeavors to maintain the efficiency of these blades by a warped construction with an impulse section at the base, a reaction section at mid-length, and a flat airfoil section at the tip.

The maximum tip speed of the last row is about 1200 fps. This is dependent upon the strength of spindle and blading material and may be increased as new alloys become available. At such high velocities on condensing turbines of the reaction type, shields are placed over the inlet faces of the last rows of revolving blades to protect them from steam erosion. Stellite appears to be a suitable protective material for this purpose. This erosion is not excessive at low blade speeds, but increases rapidly with increased blade velocities.

Aerodynamic methods have been applied to blade tests which led to improvements in design and in efficiency.

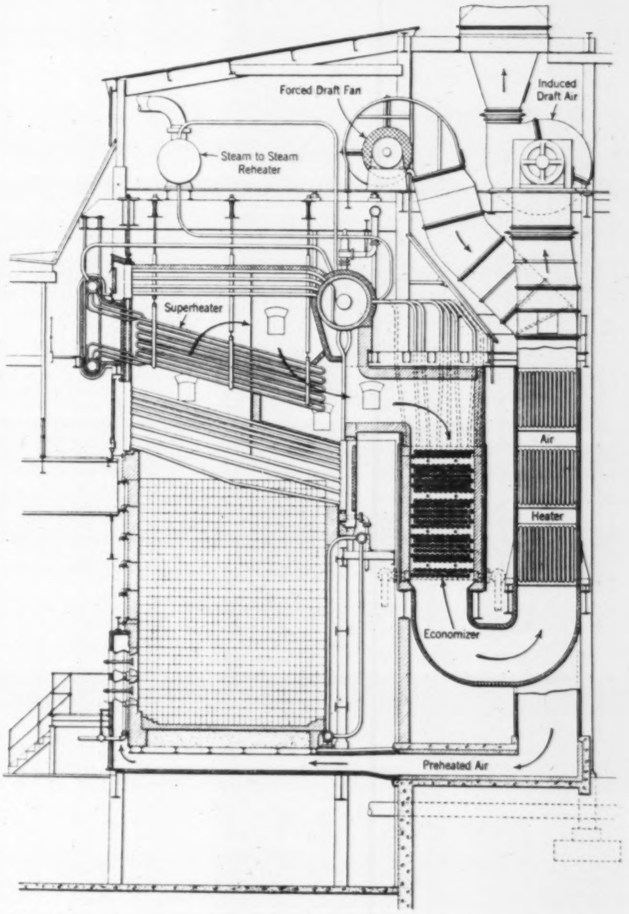

FIG. 12 FOSTER WHEELER BOILER FOR SAN ANTONIO PUBLIC SERVICE CO., 1400 LB PER SQ IN. GAGE

(See Table 3 for details.)

Initial steam conditions are usually chosen so that with the given turbine efficiency the moisture content at exhaust does not exceed 12 per cent on the Mollier diagram. While there is little experience with greater moisture contents and high tip speeds, the indications are that erosion would be increasingly rapid. Soderberg (18) has pointed out that with high tip speeds and high moisture content, the energy loss from the presence of this moisture may exceed the leaving loss. Drainage grooves have been provided in earlier stages to remove a portion of the moisture. Obviously, at best these can be only partially effective, as it is difficult to remove the minute water droplets from the rapidly moving steam without intercepting this flow and causing eddy losses. Test results indicate a removal by drainage grooves of a maximum of 25 per cent of the moisture present.

Welding has been employed to build nozzle blocks and diaphragms of impulse turbines. Improved technique in welding has resulted in better construction of these parts. Welding is employed to form cylinder bodies, exhaust shells, and even valve chests from easily made castings and structural parts.

Water-sealed glands are standard on the vacuum ends of American turbines. They are also frequently used outside the regular high-pressure steam glands to prevent steam leakage into the turbine room. Such leakage increases humidity and causes roofs to sweat in winter.

Some years ago a number of fires caused by the ignition of the lubricating oil proved disastrous in certain power plants.

With steam temperatures of from 900 to 1000 F, which are above the flash point of the lubricating oil, fire may result if this oil comes in contact with steam pipes or valves. Recent designs have embodied more rugged oil systems with reservoirs, pumps, etc., remote from the main steam supply and even in separate rooms under the turbine, so that the fire hazard is greatly reduced.

One manufacturer has used Aroclor, a noninflammable fluid, in the governor mechanism of several turbines. All recent units have totally enclosed oil control for governors. Close attention is given to lubricating oils during operation to avoid oxidation and sludging. Lubricating oil is cooled either by condensate or by raw water.

Most recently built turbines over 15,000 kw capacity have been provided with turning gears to rotate the spindle on starting up or shutting down. One manufacturer uses a motor-driven plunger pump to introduce oil at high pressure under the bearings of large units in order to float the shaft before starting to roll the turbine with the turning gear. Generally, this is not considered necessary, as the supporting oil film is quickly established from the usual oil supply of the auxiliary pump after rotation is started by the turning gear, with no apparent deleterious effect on bearings. Rotation by turning gear at 1 to 5 rpm insures even heating of spindle and cylinders and avoids any harmful deflections or distortions which would otherwise cause rubs or vibration.

Open-type extraction heaters of the jet-condenser type have been used. These have a lower terminal difference, give somewhat higher efficiency, are effective deaerators, and cost less than closed tubular heaters. On the other hand, the feedwater must be pumped between each heater and the final boiler feed pump must handle hot water. This increases the power consumption of these auxiliaries above that of a boiler feed pump delivering colder water.

Closed-type extraction heaters of both vertical and horizontal types are in extensive use. Vertical heaters are gaining in favor, as these fit well into station arrangement. The use of hairpin tubes is increasing, particularly for high-pressure heaters. Certain of the higher pressure heaters are baffled to provide counter flow of the inlet steam and thereby take advantage of the superheat to give even higher outlet water temperatures than with open heaters. Sections of other heaters are baffled to recover the heat in the condensed extracted steam by the entering feedwater. Several new designs of forged-steel heads have been developed for high-pressure heaters. Admiralty-metal tubes predominate in closed heaters, though steel and other tubes are being tried for higher pressures.

A tray-type open deaerating heater operating at slightly above atmospheric pressure at working loads is usual at one extraction point with a system of closed heaters. This deaerator removes the oxygen almost completely. It may be combined with water storage from which the boiler feed pump takes its suction. This storage water should be recirculated at all times to prevent reabsorption of oxygen.

Single-effect evaporators to furnish make-up operate at about atmospheric pressure, often taking steam from the same extraction point as the deaerator. Double-effect evaporators take steam at a higher extraction point. The evaporator condenser forms a part of the feedwater heating system.

Great progress has been made in turbogenerator design. The larger sizes of 3600-rpm generators may be hydrogen-cooled to reduce the windage losses, which are high on this type of unit. Generators have been built for voltages up to 22,000. Higher-voltage generators could be built but at a cost which may ex-

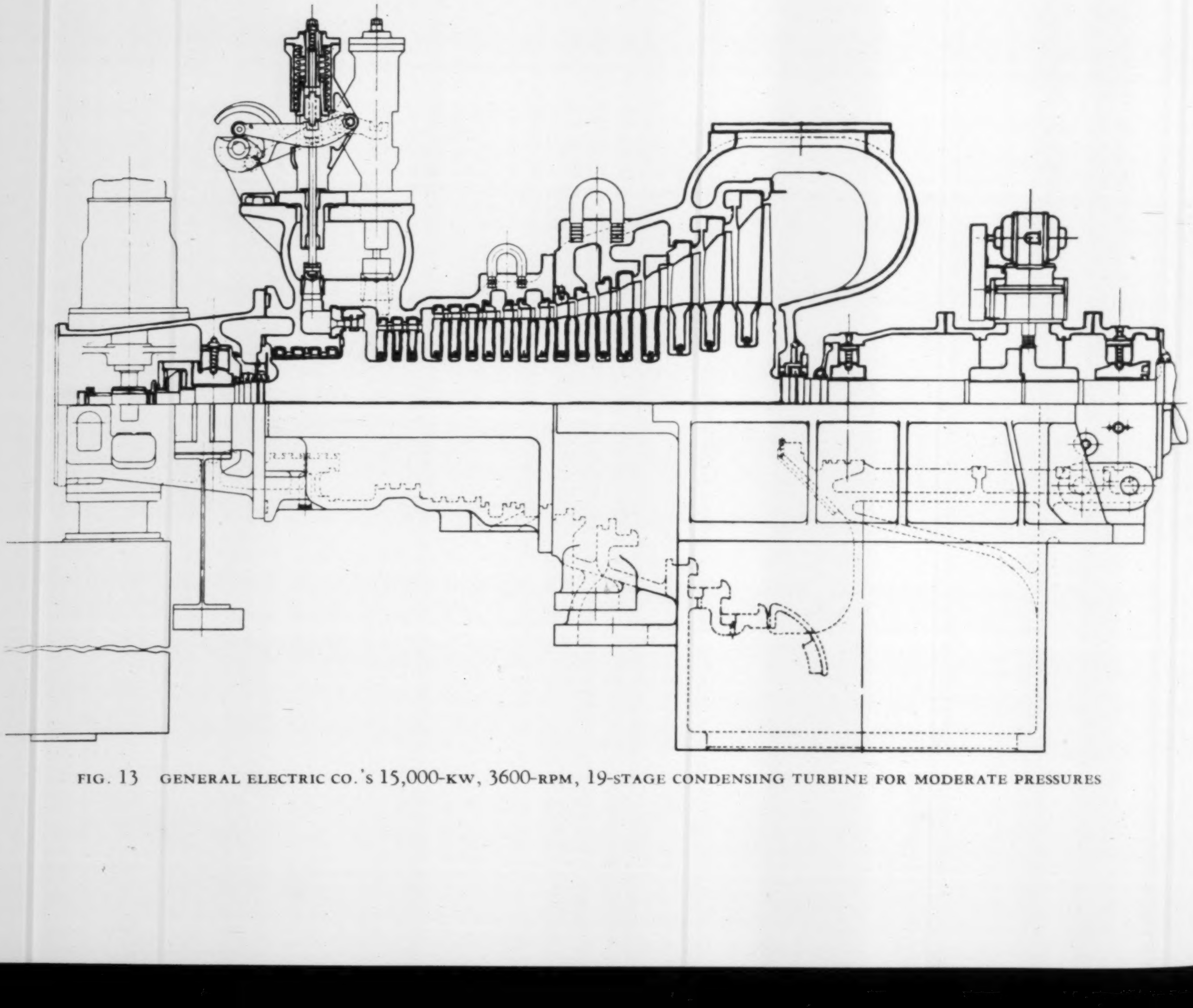

FIG. 13 GENERAL ELECTRIC CO.'S 15,000-KW, 3600-RPM, 19-STAGE CONDENSING TURBINE FOR MODERATE PRESSURES

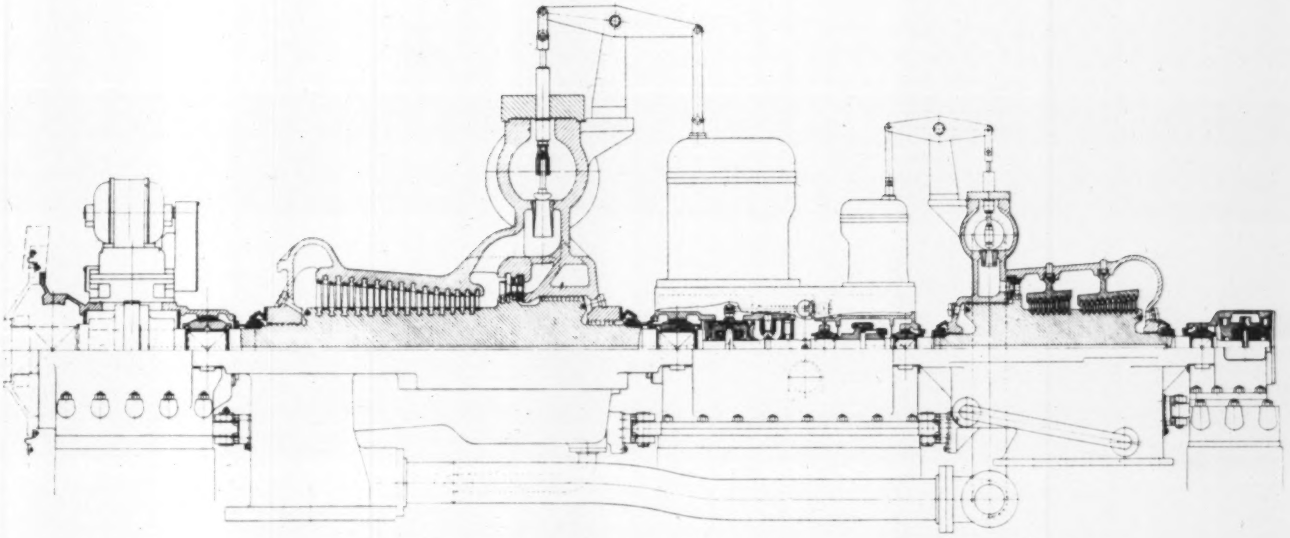

FIG. 14 50,000-KW, 3600-RPM, SUPERPOSED, NONCONDENSING TURBINE FOR WATERSIDE NO. 2 STATION, NEW YORK EDISON CO. SUPPLIED BY WESTINGHOUSE ELEC. & MFG. CO.

(Main unit—46,700 kw, 1200 lb per sq in. gage, 900 F, exhausting at 200 lb per sq in. gage. Feed-heating unit—3300 kw, 200 lb per sq in. gage, 502 F, exhausting at 5 lb per sq in. gage with extraction at 60 lb per sq in. gage.)

ceed that of the equivalent transformers and at some sacrifice in electrical protection. There have been relatively few troubles with generators in recent years, largely due to the use of generator air coolers with closed systems of air circulation. The generator air cooler sometimes forms part of the feedwater heating system with condensate used for a part or for all of the cooling.

8—CONDENSING PLANT

Many old surface condensers have a high pressure drop through the tube bank and the condensate is undercooled. Some have had the tubes rearranged; lanes have been opened up and baffles altered to decrease pressure drop and to lessen or eliminate hotwell depression.

Commercial factors controlling the design of surface condensers have been adopted by six leading manufacturers. These factors include heat-transfer coefficients corrected for tube size, water velocity, inlet-water temperature and loading, and friction losses in tubes and water boxes. Condensing surface in new units expressed as square feet per kilowatt has decreased to 0.562, due to higher available heat drops, increased turbine efficiencies, and greater extraction of steam for feedwater heating.

Lives of condenser tubes with clean fresh water are quite long. On the other hand, salt harbor water leads to early failure of tubes. Admiralty-metal tubes have been widely used with salt water, but tests indicate much longer life for aluminum-bronze and some of the more expensive nickel-alloy tubes.

Single-pass condensers are now generally used where there are adequate supplies of cooling water. Provision is made in new designs to reheat the condensate entering the hotwell to vacuum temperature. Tubes are rolled into the tube sheets at both ends in many condensers, thereby decreasing condenser leakage and impurities in the feedwater. Provision is made for expansion either by bowed tubes that permit the necessary flexure, or by a flexible element in the condenser shell, often of the bellows type. The shells of the larger and many smaller condensers are of steel, fabricated by welding. Muntz-metal tube sheets are generally specified, though steel tube sheets have been used with fresh water. Tubes up to 28 ft in length are in service. These require support plates about every 5 ft to prevent vibration.

Circulating water to many condensers is chlorinated to prevent the growth of algae and slimes inside the tubes. This treatment leads to better-sustained vacuum and lessens the necessary outages for cleaning. Table 2 shows that inlet-water temperatures vary from 31 to 88.5 F during the year.

Steam-jet vacuum ejectors are almost universally used for air pumps. The heat of the steam is recovered by inter- and after-condensers cooled by condensate. Older ejectors were two-stage units, while three-stage units are now often employed.

Motor-driven circulating pumps of vertical propeller type have been introduced to conserve floor space. Centrifugal condensate pumps usually have two stages, often with center suction to eliminate air leakage. Boiler feed pumps are generally multistage motor-driven centrifugals with a steam-driven unit in reserve and for starting-up.

9—PIPING

Increased pressures and particularly increased temperatures have given added importance to the selection and construction of proper piping materials. Creep must be considered, for all metals elongate to some extent at elevated temperatures. The problem has been to find what metals having suitable strength and ductility have creep rates within certain desirable limits.

Authorities, however, are not in full agreement with regard to desired rates of creep, for elongation is much greater during the early stages of use than later on. A tentative rate of 1 per cent in 100,000 hr is used by some designers. Metals must also resist external and internal corrosion, which may be quite rapid if oxygen is present at high temperatures.

Alloy steels, containing chrome, nickel, molybdenum, and other metals in various proportions, are in use for pipes, valves, and bolts. Stellite facings, as well as other alloys, are employed on seats and disks of valves. Practically all joints are now welded, and even valve bodies are being welded to the

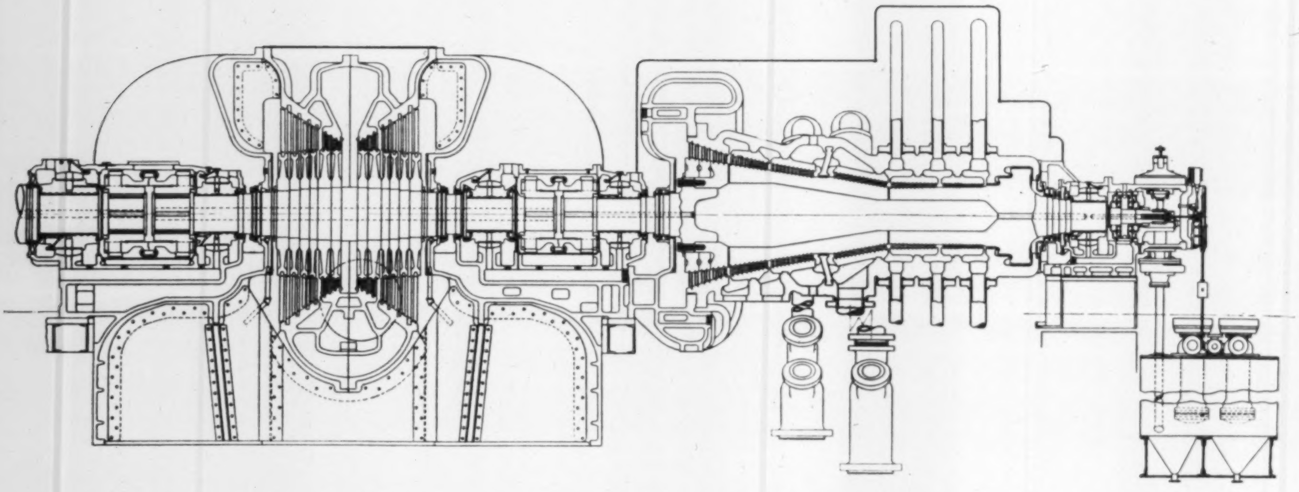

FIG. 15 80,000-KW, 1800-RPM, CONDENSING TURBINE FOR PORT WASHINGTON STATION, THE MILWAUKEE E. R. & L. CO., SUPPLIED BY ALLIS-CHALMERS MFG. CO.

(1230 lb per sq in. gage, 825 F. Reheated by flue gas, reheat to 825 F. Exhaust at 1 in. abs. Extraction at five points.)

piping. Valves can be removed from the pipe lines by cutting free with a torch. Piping materials and welding practice were discussed at length in a recent paper prepared by Dawson (19). Piping experiences with steam at 1000 F at the Delray station of the Detroit Edison Co. were discussed in a recent paper (20), while corrugated and creased-bend piping for expansion purposes has been carefully studied in a recent research (21).

10—STEAM-STATION POWER COSTS

Valuable data on public-utility plant investment and power costs have been made available through the publications of L. W. W. Morrow (22, 23). His latest paper presents data on 16 representative plants built since 1927 and ranging in capacity from 15,000 to over 200,000 kw.

Morrow found that complete investment in power plant and outdoor substation ranged from $82.50 to $145 per kw of installed capacity with an average of $114. Steam pressure had little to do with costs, as 1400-lb plants were among the highest and lowest in Morrow's tables. Heat-recovery equipment is quite expensive and increases total cost. Stations to operate at 12,000–13,000 Btu per kwhr have been built for the same price as earlier stations using 15,000–20,000 Btu per kwhr.

A comparison of the 1928 and 1935 analyses in these two papers by Morrow showed that the total cost of power per kilowatthour had not changed materially over that period. Increases in fuel, labor, and maintenance costs offset the savings from improved thermal performance. In 1934 the total cost per kilowatthour based on kilowatts delivered to outgoing lines ranged from 0.417 to 1.435 cent, with an average of 0.82 cent. Sixty per cent of this total cost was fixed charges amounting to 0.49 cent, wages 0.043 cent, and maintenance and supplies 0.067 cent. Fuel, while two thirds of the production cost, is about one fourth of the total cost. Coal costs in these stations average 14 cents per million Btu. Since total costs are affected by use factor, load factor, and fuel cost, Morrow corrected all the reported costs to a common basis of 75 per cent use factor, 50 per cent load factor, and a fuel cost of 15 cents per million Btu and found the average total cost to be 0.66 cent per kwhr. These data do not indicate lower costs for the large "superpower" type of station.

Morrow concludes that lower costs of power must come from a reduction in investment through a greater degree of standardization and simplicity in station design, greater hours' use of equipment through increased availability, and better load factors as a result of system load building.

11—MERCURY-VAPOR PLANTS

Mercury vapor is generated in three plants. The South Meadow station, Hartford Electric Light Co., contains a mercury boiler with porcupine tubes which generates vapor at 70 lb per sq in. gage. A five-stage overhung turbine of 10,000 kw capacity exhausts into two condenser boilers that produce steam at 250 lb per sq in., which, after superheating, is delivered to the main steam header for steam turbines. The furnace has air-cooled refractory side walls and was originally intended for pulverized coal, though now fired with oil. This unit has had the longest operating service of the three plants. Its average yearly heat rate is reported to be in the neighborhood of 10,700 Btu per kwhr.

A 20,000-kw mercury turbine installed at the Kearny station, Public Service Electric and Gas Co. of New Jersey, has been in service since 1933. The mercury boiler operates at 140 lb per sq in. gage. It has porcupine-tubed drums, and mercury-filled tubes form the upper side walls of the furnace. The lower section of the pulverized-coal-fired furnace contains waterwalls that generate steam at 365 lb per sq in. gage. This steam is added to that from the mercury condensers, which operate at about 27 in. vacuum, and is superheated to 750 F.

As at Hartford, the mercury turbine is placed on a floor above the mercury boiler. The turbine is a five-stage double-flow unit operating at 900 rpm. Its four exhaust openings are connected to two condenser boilers. The condensed mercury returns by gravity to the mercury boiler. Estimates of performance are difficult to make at this station, but it is said to have given substantially the same results as the Hartford plant.

A second 20,000-kw mercury unit at the Schenectady station, New York Power and Light Corp., is substantially a duplicate of the Kearny unit except that the turbine is not above the boiler. The condensed mercury is satisfactorily delivered by a centrifugal pump into the boiler. The turbine, condenser-boilers, generator, and a noncondensing 6000-kw steam turbogenerator which uses the steam from the mercury condenser, are placed out of doors. Exhaust steam from the latter unit passes at 200 lb per sq in. gage to the works of the General Electric Co.

No serious difficulties are said to have been experienced with turbines or condensers beyond leakage of air into the vacuum, which oxidized the mercury. This oxide of mercury clogged tubes in the boilers and caused overheating and a few failures. The addition of sodium and hydrogen has been tried to absorb oxygen and correct this trouble. Maintenance has been principally confined to cleaning the mercury tubes of the boiler of oxidation products and repairing the few leaks that developed. Present problems, largely of a chemical nature, appear to be about overcome. Future installations will likely be simpler and may have an improved form of mercury boiler.

Mercury detection apparatus of an electrical type has been developed that is quite sensitive. No cases of mercury poisoning are said to have occurred.

The possibilities of mercury-steam cycles was indicated by Gaffert (11), who showed that with mercury at 200 lb per sq in., 1020 F, 4 in. abs exhaust pressure, and steam at 500 lb per sq in. mercury-superheated to 800 F, with four stages of steam extraction, and 1 in. vacuum, the plant should operate at 8600 Btu per kwhr under the assumed plant conditions. This may be compared with a performance of 10,860 Btu per kwhr under similar plant assumptions for a steam plant with 1200 lb per sq in., 1000 F, and 1 in. vacuum. No figures have been released upon the first or operating costs of these mercury plants so that complete economic comparisons with steam plants may not be made.

12—ELECTRICAL SWITCHING

One of the problems in connection with the operation of large turbogenerators is the protection of the equipment against short circuits and other troubles. It is difficult to obtain circuit breakers and switches with the necessary rupturing capacity. In order to reduce the currents handled, generators are being built for high voltages and in certain cases very large generators are provided with two windings. Considerable progress has been made in switch and circuit-breaker design in recent years.

At most plants the generator voltage is stepped up for transmission purposes. The present practice is to place the transformers and other equipment in outdoor stations. This arrangement of the apparatus has given satisfactory operation under all conditions, even in Canada. Outdoor electrical stations will probably be adopted as standard practice, particularly where land is available, as it will save the cost of housing this equipment.

13—CONCLUSIONS

American power-plant practice and performance have been discussed in the preceeding paragraphs and individual trends noted.

In summary, future steam plants may be built on the unit system (one boiler per turbine), designed for high pressures and temperatures, with such heat-recovery devices as economizers, air heaters, and extraction heaters, which equipment, with due consideration of fuel cost, reliability, and operating convenience, will deliver power from the station at a minimum unit cost.

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POWER PAPERS FOR NIAGARA FALLS MEETING IN THIS ISSUE

THE FOREGOING paper by A. G. Christie, and the three papers which follow in this issue, are to be presented at the Niagara Falls Meeting, September 17 to 19, of The American Society of Mechanical Engineers, as contributions by the Power Division.

Other papers on power subjects, not published in advance of the meeting, are being contributed by the Fuels and Hydraulic Divisions. Two of the papers on hydraulics will review hydroelectric plants in the United States and Canada, and two will summarize the equipment and work of hydraulic laboratories in America.

The Railroad, Aeronautic, Woodworking, and Process Industries Divisions are also holding technical sessions at Niagara Falls.

For a more detailed description of the program, see pages 604 to 607 of this issue.

SUPERPOSITION

Factors Involved in Adding High-Pressure Boilers and Turbines to Existing Plants

By E. H. KRIEG

AMERICAN GAS AND ELECTRIC COMPANY

By MEANS of superposition, 4000-Btu-per-kwhr capacity is added to an existing plant at a cost of from $80 to $110 per kw, so that a plant performance of, say, 24,000 Btu per kwhr is decreased to 12,500 Btu per kwhr. Of course, these figures vary widely under different conditions and depend upon favorable or unfavorable circumstances.

In a superposition plant a new high-pressure boiler (600 to 1400 lb) supplies steam to a new high-pressure turbine which exhausts into the old low-pressure (usually about 200 lb) turbines. Simply expressed, superposition is a method of cross-compounding by exhausting a high-pressure turbine to the existing low-pressure turbines, and replacing the old low-pressure steam generators with a high-pressure steam generator. The old generator may be kept for reserve when the high-pressure element is not in operation.

Superposition is not a recent or novel idea, but the use of units for 1250 lb per sq in. and 925 F with a regenerative cycle without reheat is quite recent, as is also the development of hydrogen-cooled generators in sizes up to 50,000 kw running at 3600 rpm.

WHERE SUPERPOSITION HAS BEEN APPLIED

Before examining the possibilities of superposition, applications that have already been made will be reviewed. Several successful superposed plants have been built, but the term "superposition" has never been applied to them. Superposition has come to connote the rehabilitation of existing plants in efforts to postpone obsolescence, whereas in the following examples of superposition that was, perhaps, not the primary purpose. These plants are as follows:

Plant	Company
Edgar	Edison Electric Illuminating Co. of Boston
Deepwater	Houston Lighting and Power Company
Northeast	Kansas City Light & Power Company
Lakeside	Milwaukee Electric Railway and Light Co.
Burlington	Public Service Electric & Gas Company

The last-named plant was definitely called a superposed plant.

Each of the plants listed not only has one or more high-pressure units exhausting into low-pressure units, but also has low-pressure boilers, some of which are continuously in operation, as is indicated in Table 1.

Some other plants differ from superposed plants only because they have no low-pressure boilers that might be used to run the low-pressure turbines independently of the high-pressure units, which is possible in superposed plants. At these plants, if the high-pressure turbines fail, a pressure-reducing system automatically acts to supply steam from the high-pressure boilers at reduced pressure to the low-pressure turbines, which will stay in service. Similarly, in superposed plants, such a system may be provided if it is found to be justified. In so far as the turbine room is concerned, the Deepwater station in New Jersey, the 165,000-kw unit at Philo, and some others are essentially of the superposed type.

At the Cabin Creek plant of the Appalachian Electric Power Company a 5000-kw (400 lb, 725 F) turbine exhausts at 250 lb and 600 F into two turbines one of 20,000 kw and the other of 25,000 kw capacity. This, of course, is a true superposed plant, as it was installed for the purpose of postponing the obsolescence of the two 250-lb units by increasing efficiency. No special boilers were installed, as there already existed two 400-lb, 725 F, units with capacities of 20,000 kw and 31,500 kw and the necessary boilers.

WHERE SUPERPOSITION IS BEING APPLIED

The aforementioned plants were the background for the advent of modern 1200-lb, 925-F superposition, which owes a great deal to the experience gained with 1200-lb reheat plants using steam temperatures up to 750 F; 600-lb plants using temperatures up to 825 F; and the 400-lb, 1000-F unit at Delray. Such plants gave the necessary metallurgical experience for bolting materials and castings, developed welded piping, and showed that boilers could be designed for high availability, output, and temperature. They provided the testing ground from whence came confidence in materials for temperatures of 925 F and pressures of 1350 lb.

Table 2 lists most of the superposed plants that are under construction or that have been built.

WHERE SUPERPOSITION CAN BE APPLIED—JUSTIFICATION

In line with the policy of keeping in mind that whether a system needs new capacity or not, it should be known at all times what opportunities exist for making a profitable investment, studies were made by the American Gas and Electric Company continuously from 1933 on as to whether any type of rehabilitation justified new investment. At that time, the present rate of load increase was not wholly anticipated. These studies included:

1 Rehabilitation of existing units and changes to the station cycle for more capacity and better efficiency as was done at Conners Creek

2 Extensions similar to existing units at the same pressure and temperature

3 Entirely new stations

4 Superposition of a high-pressure, high-temperature unit exhausting into existing turbines.

Even when new capacity is required, it is still necessary to determine the best method of adding it and to study the problem from much the same viewpoint as when no new capacity is needed. In 1933 and 1934 these studies emphasized the carrying of the new investment with the savings made possible by lowering the operating costs of the plant to be superposed,

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Contributed by the Power Division for presentation at a meeting, Niagara Falls, N. Y., Sept. 17–19, 1936, of The American Society of Mechanical Engineers

TABLE 1 DATA ON EXISTING SUPERPOSED INSTALLATIONS

HIGH-PRESSURE BOILERS	No. 1	No. 2	No. 3	No. 4
Total no.	4	2	2	1
Max capacity, each, 1000 lb per hr	300	230	350	600
Design superheater outlet press, lb per sq in. gage	1390	1390	1365	673 (a)
	1 unit 3 units			
Design superheater outlet temp, F	725 750	725	850	860
1934 hours in operation	27,568.75	...	8322–8169	7884
1934 hours on bank	3,610.25	...	None	14
1934 hours unavailable	2,090.25	...	438–591	768
Feed temp, avg for 1934, F	310	325	341	340
Make-up, avg for plant, 1934, per cent	2.33	...	2.5	1.84
Type make-up	Condensate	Condensate	Evaporated	Evaporated
1934 avg efficiency, per cent	86.38	85	81.4	84.0
1934 avg reheat press, in—out, lb per sq in. gage	310–290	315–290 (g)	1270–335	No reheat
1934 avg reheat temp, in—out, F	447–735	450–700	835–737	No reheat
LOW-PRESSURE BOILERS				
Total no.	16	12	4 2	10
	8 units 8 units			8 units 2 units
Max capacity each, 1000 lb per hr	100 150	120	240–350	50 100
Design superheater press, lb per sq in, gage	317	290	365–375	200
Design superheater temp, F	720	650–700	750–750	550
Availability	Not determined	(c)	(k)	...
Feed temp, avg for 1934, F	199	235	314–314	212
Make-up, avg for plant, 1934, per cent	2.33	3	2.5–2.5	...
Type make-up	Raw water	(d)	Evaporated	Evaporated
1934 avg efficiency, per cent	85.82	80 (e)	...	71
Are l-p boilers operated while h-p boilers are on? Per cent of time	Yes—100	Yes—75	Yes—100	In general No
Are l-p boilers kept on bank to back-up h-p boilers? Per cent of time	(b)	— (f)	Yes—100	In general No
Are l-p boilers operated only when h-p boiler is off?	Yes	No	...	In general Yes
Are l-p boilers ever operated at all?	Yes	Yes, 75% of time	Yes	Yes
HIGH-PRESSURE TURBINES				
Number	4	1	1	1
Capacity of each, kw	7,700	10,000	12,000	18,000
H-p exhaust developed in l-p turbines, kw	24,300	36,000	40,000	37,000
1934 avg throttle press, lb per sq in., gage	1,237	1,280	1,270	645
1934 avg throttle temp, F	735	725	710	840
1934 avg exhaust press, lb per sq in., gage	310	315	351	151
1934 avg exhaust temp, F	447	450	458	556
1934 hours in use	25,917.5	7,000 (h)	8,668	7,644
1934 hours unavailable	463.0	1,730	92	782
1934 hours stand-by (idle hours)	8,659.5	None	None	334
1934 generation, 1,000,000 kwhr	166	53	102	109
LOW-PRESSURE TURBINES				
No. installed	8	5	5	3
No. of units	2 4 2	2 3	2 1 2	
Capacity of each, 1000 kw	20.0 30.0 60.0	30 23	20 25 35	12.5
1934 avg throttle press, lb per sq in., gage	283	270	335 335 335	151
1934 avg throttle temp, F	694	675	737	556
1934 avg vacuum, 30-in., in	0.90	1.2	1.71	1.66
Availability, per cent	91.0	...	Station 91.01	90
1934 generation, 1,000,000 kwhr	718	391	400	200
GENERAL				
Into what l-p turbines can each h-p turbine exhaust (give unit numbers)	Any of 4 h-p exhausts into any of 8 l-p	Any of 5, but more direct to the 30,000's	Any l-p turbine	1 h-p exhausts into 3 l-p
Type of reheater	1 Radiant 3 Convection	Radiant	Steam–Steam	None
PERFORMANCE FOR YEAR 1934				
Btu per kwhr with h-p	12,847	14,386 (1932 net)	14,225	15,616 (j)
Btu per kwhr only l-p	16,180	17,900 (1932 net)	17,000	...
Water rate with h-p (for station), lb	9.064	9.43 (1932 gen)	10.88 (l)	11.53
Water rate with l-p (for station), lb	11.643	11.00 (1932 gen)	12.46	
Auxiliary power, per cent of total generation (not of net)	6.37 {6.40 h-p 6.26 l-p}	6.36 (i)	6.8	5.82
Yearly load factor, h-p, per cent	63.51	75.5	97.1	64
Yearly load factor, l-p, per cent	21.20	68.8	...	71
Yearly plant capacity factor, h-p, per cent	62.32	75.5	63.9	55
Yearly plant capacity factor, l-p, per cent	11.57	31.8	...	61
Yearly plant capacity factor, plant	...	...	...	59

NOTES:

[a] At 525,000 lb per hr.
[b] No, but sufficient capacity in operation is available in case one high-pressure boiler is lost.
[c] Use only 6 of 12 boilers, so availability not considered.
[d] City water with lime and soda-ash treatment.
[e] 80 per cent steaming, 78 per cent including banks.
[f] Enough steaming or banked to pick up load of one high-pressure boiler.
[g] Includes loss through connecting piping.
[h] Unusually low because installation steam scrubbers in both boilers, also out 6 weeks to reconstruct packing.
[i] Per cent of auxiliary power of total generator without high-pressure unit = 4.5.
[j] Best month to date, 14,820, March, 1934.
[k] Availability higher than usual because usual overhaul period not included in this period.
[l] Includes steam for condensing reheaters.

assuming no load increase on the system. However, the savings in production costs did not carry the investment with sufficient margin of savings to warrant the adventure until new capacity was needed. In any event, the problem is chiefly affected by the investment to be carried, and old and new production costs on the system, i.e., savings.

INVESTMENT

The investment to be carried is a matter for individual determination. The fact that one company believes that a superposed installation will cost $80 per kw whereas another feels that it cannot be made for less than $110 per kw is not a matter that can be settled casually. The many physical differences in plants render accurate comparison of investment costs impossible. In one plant it may not be necessary to do anything to an existing building for the installation of the high-pressure boiler and turbine, whereas in another so much usable existing equipment may have to be removed and the building so greatly remodeled that it is cheaper to build an entirely new station. In addition, there are as many ways of preparing a cost estimate as there are individuals to prepare it. The same applies to what proportion of old capital must be carried by the new investment; although it is generally true that if the saving made by a new investment carries that investment, it automatically carries the old investment also.

Little is to be gained in presenting cost estimates. It is well known how much investment costs vary and it is believed that the yardstick is not what some other system does or did, but what effect a superposed unit would have on its own system. It may suffice to state that most studies showed that large superposed units could be installed for from $80 to $90 per kw. Under other conditions these estimates could be lower, and easily higher in the case of small units.

The first superposition studies were not attractive financially except in cases where the additional capacity was needed. It appeared that to improve the efficiency of the plants considered it would be necessary to reduce the investment by using as large a turbogenerator as possible, and by using a single boiler if possible.

SIZE OF TURBOGENERATOR

The installation of as large a unit as possible had not only the obvious advantage of a lower investment cost per kilowatt but also made it possible to get a maximum number of kilowatt-hours per year out of the plant, for these plants were part of a system on which practically no load increase was assumed. Even if new capacity is needed, much the same viewpoint is required. Therefore, to obtain the highest financial return the operating savings in fuel, labor, and maintenance were to be as high as possible, and the investment was to be as low as possible. The largest amount of new superposed capacity per kilowatt of existing low-pressure capacity was found to offer the best return as it accomplished both of these fundamental economies.

The foregoing statement is limited to complete superposition where all of the existing low-pressure turbines receive steam supply from the superposed turbine. In many cases there is too much low-pressure turbine capacity to permit superposition by a single unit. But even in such cases it may be safe to make the generalization that the partial superposition should be so planned that ultimately, when system conditions require complete superposition, the highest possible ratio of superposed capacity to existing low-pressure capacity will be obtained.

Having decided that the larger the unit the lower the investment and the more savings possible from greater output, the problem was discussed with the turbogenerator manufacturers as to how to increase the sizes available. In 1933, 25,000 kw was the largest 3600-rpm turbogenerator offered. Designs were then developed for 30,000 kw, which appeared to be the ultimate for air-cooled generators at 3600 rpm. The next problem was whether to drop to 1800 rpm above 30,000 kw, or to go to hydrogen-cooled generators. The 1800-rpm alternative involved a sacrifice in turbine efficiency and a higher cost per kilowatt, whereas hydrogen cooling with 3600-rpm turbines held the promise not only of high turbine efficiency and smaller parts exposed to high temperature, but also much higher generator efficiency through decreased windage losses amounting to about 450 kw in a large unit, or a little more than one per cent.

At that time many hydrogen-cooled synchronous condensers had been in operation as far back as 1928. True, these had no rotating shafts piercing the end bells through which hydrogen would leak, but beyond this there seemed to be no other inherent difficulty. Concentration on a shaft seal that would be tight with hydrogen produced a design that appears satisfactory. The solution of this problem increased the size range first to 38,000 kw and, with aluminum rotor windings, to 50,000 kw, which is not the present limit. A 75,000-kva, 3600-rpm unit can now be obtained. Figs. 1, and 2, show typical recent turbines.

Obtaining as large a superposed unit as possible for the amount of existing low-pressure capacity also brings to mind the possibility of using turbine-driven auxiliaries if the existing units cannot furnish as much bleed steam as the feedwater system can absorb. This will be mentioned later in more detail.

The advantages of a single 40,000-kw hydrogen-cooled unit

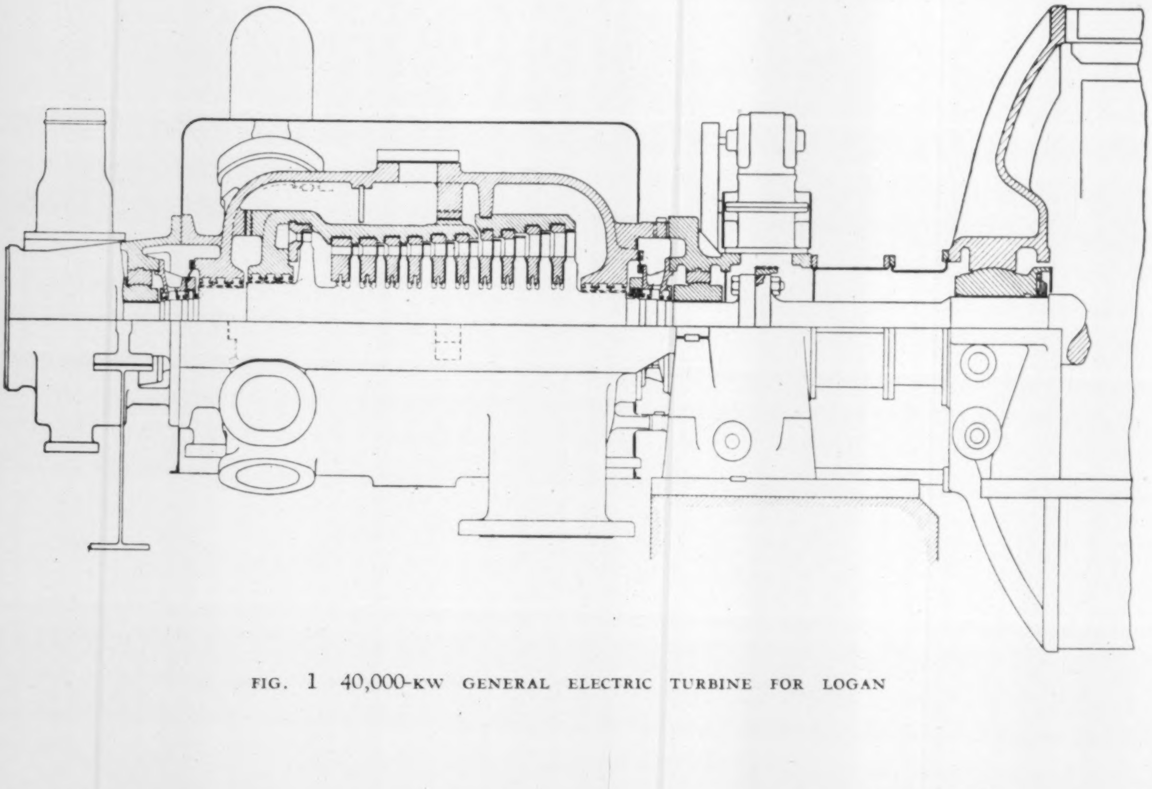

FIG. 1 40,000-KW GENERAL ELECTRIC TURBINE FOR LOGAN

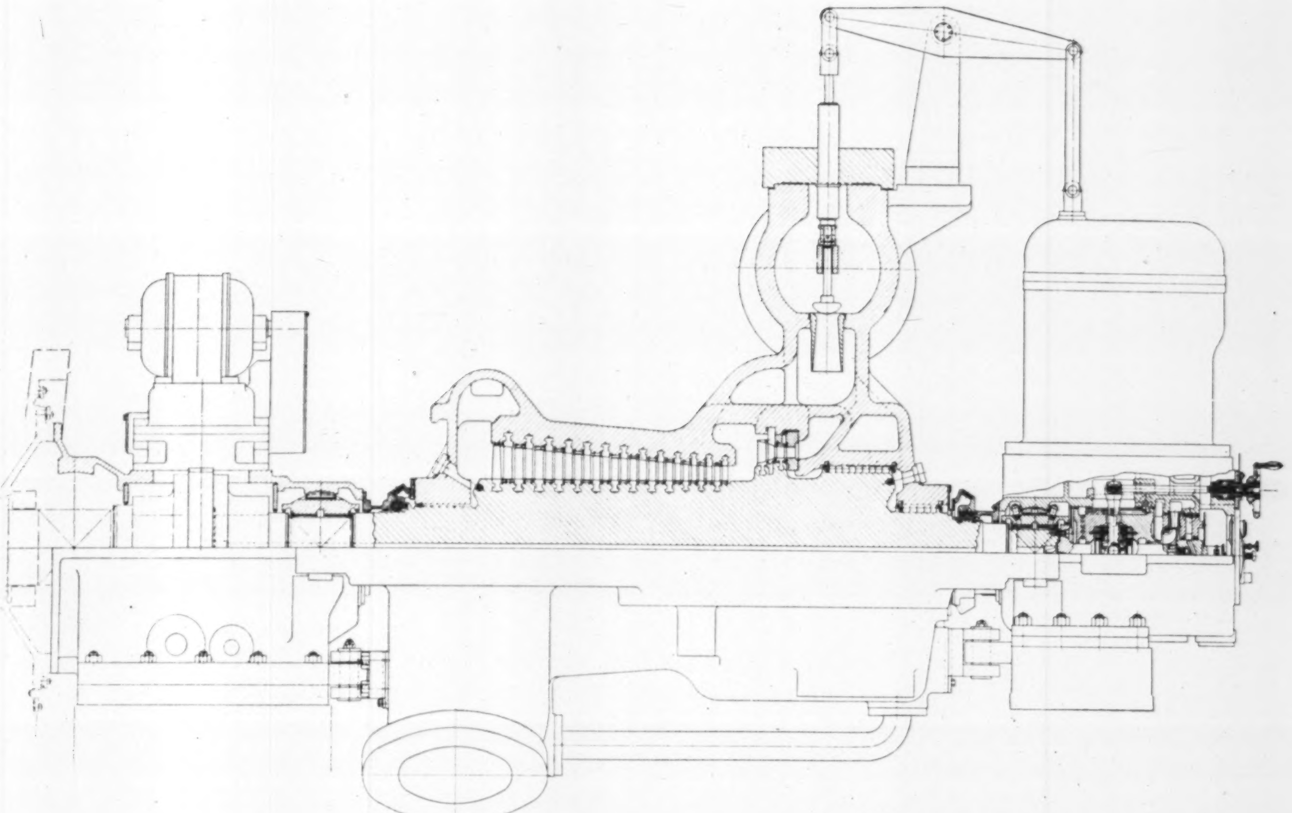

FIG. 2 35,000-KW WESTINGHOUSE TURBINE FOR WEST END

over two 20,000-kw air-cooled units at Logan may be briefly mentioned:

(1) Lower investment in turbogenerator equipment, foundations, piping for 1250-lb, 925-F steam, exhaust steam, relief valves, instruments, lubricating-oil system, and electrical equipment.

(2) Space limitations precluded the use of two units.

(3) Higher generator efficiency with hydrogen-cooling, with practically no difference in investment.

(4) Lower maintenance, as maintenance notably decreases with size of units.

It should be mentioned also that the system to which the unit is connected has a peak in excess of 700,000 kw.

SINGLE-BOILER PLANTS

Some judgment is required to decide whether or not a single-boiler installation is suitable for a given set of conditions. That such an installation may be found desirable is borne out by the following single-boiler installations:

Plant	Boiler capacity, lb per hr	Turbine capacity, kw
Port Washington	690,000	80,000
San Antonio, Station B	215,000	8,000 h-p 25,000 l-p
Duluth, Minn	300,000	25,000
Burlington	600,000	18,000 h-p 36,000 l-p
Ford, River Rouge	900,000	110,000

In several plants the number of boilers and turbines is the same, and no spare boiler is provided; e.g., Lakeside, Bremo Bluff, K Street, Gould Street, Rio Grande, and Ohio River.

Obviously, such installations could not well be made on an isolated system having insufficient reserve. Conditions favorable to a single-boiler installation are more likely to exist on a large interconnected system where sufficient spinning reserve is maintained and where plants with high operating cost are available for emergencies. In the case of the Logan plant of the Appalachian Electric Power Company it was physically impossible to provide more than one boiler because of building and property space limitations that could not be extended.

Boiler availability has been considerably improved in recent years until it is now equaling, and in some cases surpassing, turbine availability. It has become possible to schedule boiler outages with the same regularity as turbine outages. With a boiler designed for such availability there appears to be little economic justification for the extra cost of a multiple-boiler plant on an interconnected system where the necessary safeguards exist. At Lakeside, boiler availabilities of 94.7 per cent for 1934, 98.1 per cent for 1933, 97.1 per cent for 1932, and 95.2 per cent for 1931 have been attained on three 1250-lb, 750-F boilers.

With a two-boiler installation for a superposition plant, care must be exercised in operating with one boiler out of service under partial load, because the exhaust temperature from the superposed turbine may become too high for the old low-pressure turbines. A single boiler does not have this disadvantage as superheater temperature decreases with load. Of course, if the old turbines are good for high temperature or if the boiler superheat can be greatly decreased by by-passing the superheater, this disadvantage disappears.

It should be noted that in several cases it was cheaper to install several boilers rather than one large boiler in order to use an existing building which otherwise would require alteration in order to house a single large boiler. Thus the overall building and multiple-boiler cost was less than that of a single-boiler installation. Typical steam generators now available are shown in Figs. 3 and 4.

PRODUCTION COSTS AND SAVINGS

Maximum operating savings imply the lowest possible operating costs consonant with the investment required. The accountants may itemize such costs as operating labor, maintenance, supplies, etc., but more fundamental than these is output or capacity use. Optimum output can be fairly estimated from the data given in the turbine reports of the Edison Electric Institute and its predecessor, the National Electric Light Association.

AVAILABILITY AND MAXIMUM OUTPUT

The most generally useful factor given in the various turbine reports is probably service demand availability, which indicates the percentage of the time the turbine is available when needed. Unit-operation factors are more a function of the system characteristics and hence must be used with some judgment. From Table 3, it will be seen that this factor for 550- to 1000-lb turbines for the years 1925, 1928, 1929, and 1930 was, respectively, 90.93, 94.90, 96.90, and 95.81 per cent.

From Table 4 it will be seen that for turbines for pressures of around 1200 lb per sq in. this factor for the years 1930, 1931, 1932, 1933, and 1935 was, respectively, 82.68, 88.78, 88.36, 91.72, and 90.03 per cent. It must be realized, and can readily be seen from Table 4, that these ratios could have been much higher except for a comparatively few turbines which had exceptionally low factors that brought the average down. For example, in 1935, nine turbines out of twelve had service demand availabilities of 94 per cent or more. In 1933 there were five turbines with 100 per cent service demand availability and seven more that ranged from 92.95 to 98.83 per cent, a total of twelve out of fifteen. In 1932 and also in 1931, eight turbines out of twelve had 90 per cent, or better, availability.

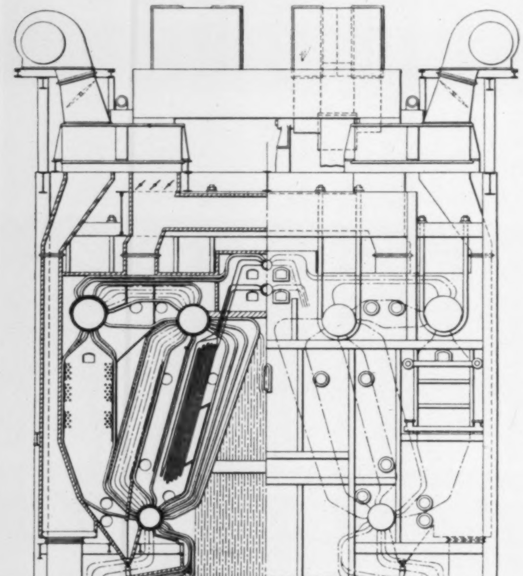

FIG. 3 COMBUSTION ENGINEERING COMPANY STEAM GENERATOR FOR LOGAN

(1,000,000 lb per hr, 1325 lb per sq in., 925 F.)

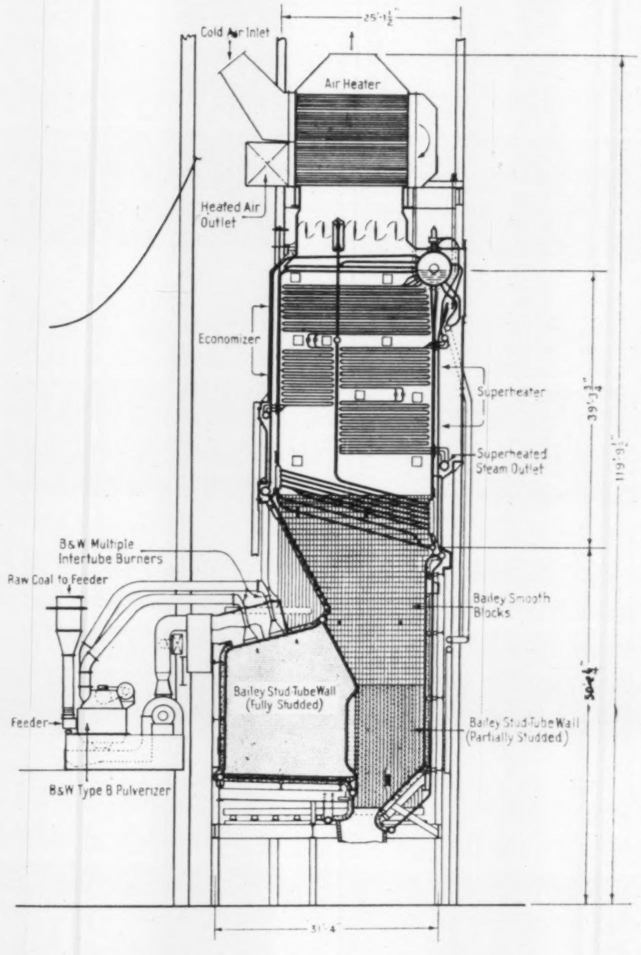

FIG. 4 BABCOCK & WILCOX STEAM GENERATOR FOR SPRINGDALE

(575,000 lb per hr, 1270 lb per sq in., 935 F continuous slag tap.)

From Tables 1, 3, and 4, especially considering the improvement in turbine design that has occurred since these turbines were installed, it appears that a turbine service demand availability factor of 92 per cent or greater may confidently be expected on the whole, even from these old designs. For new turbines it is believed that a turbine availability of 95 per cent is not unduly optimistic, as will be seen from the service demand availability record of the following four turbines:

Year	Unit 50–10	Unit 50–8	Unit 50–12	Unit 50–9
1931	98.35	100.00	100.00	98.83
1932	99.10	97.40	98.50	98.00
1933	97.57	93.35	94.97	95.38

TABLE 2 DATA ON SUPERPOSED POWER STATIONS

	Pressures up to 825 lb per sq in.								
Company	Appalachian El. Pr. Co.	Hawaiian El. Co.	Pub. Ser. El. & G. Co.	Laclede Pr. & Lt. Co.	Rochester Gas & El. Co.	Virginia El. & Pr. Co.	Iowa El. Lt. & Pr. Co.	United Ill. Co.	Consolidated Pr. Co.
Station	Cabin Creek	Honolulu	Burlington	Mound St.	Station 3	12th St.	Cedar Rapids	Steel Point	Elm St.
Location	Cabin Creek, W. Va.	Hawaii	Burlington, N. J.	St. Louis, Mo.	Rochester, N. Y.	Richmond, Va.	Cedar, Rapids, Iowa	Bridgeport, Conn.	Battle Creek, Mich.
Operation began	1930	Oct. 29, 1933	Nov. 24, 1933	June 10, 1936	Jan. 1, 1936 1–1937	1936	1936	1937	1937
Superposed Turbogenerator									
Capacity, kw	5000	10,000	18,000	5000	6000	12,500	5000	5000	10,000
Make	G. E.	West.	West.	A.-C.	G. E.	G. E.	G. E.	G. E.	G. E.
Speed, rpm	3600	3600	3600	3600	3600	3600	3600	3600	3600
Power factor, per cent	80	80	80	80	80	80	70	80	80
Constant back-press	Yes	...	Yes	Yes	Yes	Yes		...	...
Cooling	Air	Air	Air	Air	Air	Air	Air	Air	Air
Operating Conditions									
Throttle press., lb per sq in.	400	650	650	450	650	825	650	600	750
Temp, F	725	825	825	850	750	825	712	840	850
Exhaust press	250	265	205	185	210	220	210	210	210
Temp, F	600	...	...	485	530	540	540	...	...
Low-Pressure Units									
Total L-P kw served by superposed unit	45,000	...	37,500		25,000	21,000	...	...	...
Individual L-P units, kw	25,000 20,000	3—10,000	3—12,500	2—7500 G.E. 5000 West. 3500 G.E.	15,000 10,000	...	...	...	...
High-Pressure Boilers									
Number	*b*	1	1	2	2	1	1	2	1
Capacity, each, lb per hr	...	...	550,000	...	250,000	450,000	300,000	125,000	360,000
Superheater press., lb per sq in	...	650	700	450	660	860	700	615	900
Temp, F	...	825	850	850	750	835	765	850	875
Make of boiler	...	...	C. E.	Springfield	C. E.	C. E.	Springfield	B. & W.	B. & W.
Area, sq ft	...	9380	30,300	13,500	15,300	24,930	13,600	11,100	4134
Superheater, make	...	...	Elesco	...	Elesco	Elesco	Elesco	B. & W.	B. & W.
Area, sq ft	...	...	10,700	...	10,613	8,650	...	4,050	10,750
Economizer, make	...	...	None	...	F. W.	...	F. W.	...	B. & W.
Area, sq. ft	...	...	...	...	20,808	...	4608	...	21,360
Air heater, make	...	...	C. E.	...	...	Ljung.	Ljung.	B. & W.	B. & W.
Area, sq ft	...	...	41,800	...	...	32,200	16,800	10,320	67,733
Waterwall, make	...	...	C. E.	...	C. E.	C. E.	LaMont	...	...
Area, sq ft	...	...	4110	...	3990	11,060	2150	...	...
Furnace-bottom type	...	...	Dry	Natural gas	Dry	Wet	Stoker	Dry	Dry

TABLE 2 DATA ON SUPERPOSED POWER STATIONS (*Continued*)

	Pressures around 1200 lb per sq in.								
Company	Edison Elec. Ill. Co.			Milwaukee Elec. Ry. & Lt. Co.		Kansas City Pr. & Lt. Co.		Amer. Lt. & Trac. Co.	Houston Lt. & Pr. Co.
Station	Edgar			Lakeside		Northeast		Station B	Deepwater
Location	Weymouth, Mass.			St. Francis, Wis.		Kansas City, Mo.		San Antonio, Tex.	Houston, Tex.
Operation began	Jan., 1925	1927	Nov., 1929	Oct., 1926, 1927 and 1930		July, 1929		Sept., 1930	1931
Superposed Turbogenerator									
Capacity, kw	3360	10,000	12,500	1–7000	3–7700	12,500		8000	12,000
Make	G. E.	G. E.	G. E.	G. E.	G. E.	West.		West.	G. E.
Speed, rpm	3600	3600	3600	3600	3600	3600		3600	3600
Power factor, per cent	100	80	80	90	96	80		100	80
Constant back-press	Yes	Yes	Yes	Yes	Yes	Yes		No	Yes
Cooling	Air	Air	Air	Air	Air	Air		Air	Air
Operating Conditions									
Throttle press., lb per sq in.	1075	1200	1200	1200	1200	1200		1325	1300
Temp, F	700	700	700	750	750	725		800	725
Exhaust press	365	375	375	317	317	315		180	380
Temp, F	...	...	...	...	...	...		Variable	725
Low-Pressure Units									
Total L-P kw served by superposed unit	...	...	...	...	120,000	...		12,500	40,000
Individual L-P units, kw		2—38,000 1—65,000			2—20,000 4—30,000 2—60,000	2—30,000 3—29,000		12,500	2—20,000 1—25,000 2—35,000
High-Pressure Boilers									
Number	1	2	2	1	3	2	1	1	2
Capacity, each, lb per hr	143,000	250,000	300,000	240,000	250,000	230,000	300,000	215,000	350,000
Superheater press., lb per sq in	1200	1400	1400	1300	1300	1275	1275	1325	1325
Temp, F	700	733	750	725	750	725	815	810	850
Make of boiler	B. & W.	B. & W.	B. & W.	B. & W.	C. E.	C. E.	C. E.	F. W.	B. & W.
Area, sq ft	15,613	15,093	6971	30,590	28,845	16,950	3500	4990	7778
Superheater, make	B. & W.	B. & W.	B. & W.	F. W.	F. W.	Elesco	Elesco	F. W.	B. & W.
Area, sq ft	...	...	...	Rad. 910	Rad. 1125	...	5170 (*a*)	4640	8200
Economizer, make	B. & W.	B. & W.	B. & W.	None	None	Elesco	Elesco	F. W.	B. & W.
Area, sq ft	11,487	5596	9634	...	...	10,891	10,000	11,880	13,820
Air heater, make	...	B. & W.	B. & W.	C. E.	C. E.	C. E.	Ljung.	F. W.	B. & W.
Area, sq ft	None	33,032	29,665	67,300	77,500	39,270	36,800	13,900	31,154
Waterwall, make	...	...	...	B. & W.	...	C. E.	C. E.	B. & W.	B. & W.
Area, sq ft	None	1235	1206	2070	5205	3050	3970	1011	1156
Furnace-bottom type	Stoker	Stoker	Stoker	Dry	Dry	Dry	Wet	Gas or oil	Gas-fired

NOTES:
a = Reheater Elesco, 5700 sq ft; *b* Uses boilers installed for 1—31,500 kw and 1—25,000 kw, 400 lb units; G. E. = General Electric; West. = Westinghouse; A.-C. = Allis-Chalmers; B. & W. = Babcock & Wilcox; C. E. = Combustion Engineering; F. W. = Foster-Wheeler; Ljung. = Ljungstrom.

TABLE 2 DATA ON SUPERPOSED POWER STATIONS (*Continued*)

	Pressures around 1200 lb per sq in.							
Company	Monongahela West Penn Pub. Ser. Co.	West Penn Power Co.	Commonwealth Edison Co.	Nebraska Power Co.	Appalachian El. Pr. Co.	N. Y. Edison Co.	Union Gas & El. Co.	Dayton Pr. & Lt. Co.
Station	Rivesville	Springdale	Fiske St.	Omaha	Logan	Waterside No. 2	West End	Millers Ford
Location	Rivesville, W. Va.	Springdale, Pa.	Chicago, Ill.	Omaha, Neb.	Logan, W. Va.	New York	Cincinnati, O.	Dayton, O.
Operation began	1937	1938	1938	1937	1937	1937	1937	1937
Superposed Turbogenerator								
Capacity, kw	25,000	50,000	30,000	10,000	40,000	50,000	35,000	25,000
Make	G. E.	West.	A.-C.	G. E.	G. E.	West.	West.	G. E.
Speed, rpm	3600	3600	1500	3600	3600	3600	3600	3600
Power factor, per cent	100	90	95	80	80	85	80	80
Constant back-press	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cooling	...	Hydrogen	Air	Air	Hydrogen	Hydrogen	Hydrogen	Hydrogen
Operating Conditions								
Throttle press., lb per sq in.	1200	1235	1200	1200	1250	1200	1215	1200
Temp, F	925	925	900	900	925	900	900	900
Exhaust press	260	340	220	200	200	200	275	230
Temp, F	...	...	525	560	495	...	...	535
Low-Pressure Units								
Total L-P kw served by superposed unit	40,000	...	60,000	15,000	50,400	60,150	70,000	...
Individual L-P units, kw	....	2—20,000 2—30,000 1—40,000	25,000 35,000	....	2—18,000 3— 4,800	35,000 35,000	2—35,000	110,000 in 6 units
High-Pressure Boilers								
Number	2	3	2	1	1	2	3	2
Capacity, each, lb per hr	362,000	575,000	412,500	275,000	1,000,000	500,000	350,000	375,000
Superheater press., lb per sq in	1240	1270	1275	1250	1325	1325	1275	1250
Temp, F	915	935	910	910	925	900	925	900
Make of boiler	B. & W.	B. & W.	B. & W.	C. E.	C. E.	C. E.	B. & W.	B. & W.
Area, sq ft	4866	6369	66,400	12,000	20,800	7008	7176	3367
Superheater, make	B. & W.	B. & W.	B. & W.	Elesco	Elesco	Elesco	B. & W.	B. & W.
Area, sq ft	14,100	19,070	18,600	9720	24,720	14,000	7357	10,460
Economizer, make	B. & W.	B. & W.	B. & W.	Elesco	2 Elesco	Elesco	B. & W.	B. & W.
Area, sq ft	11,925	16,700	11,700	18,130	25,850T	18,850	15,191	21,000
Air heater, make	B. & W.	B. & W.	B. & W.	Ljung.	2 Ljung.	Ljung.	B. & W.	B. & W.
Area, sq ft	22,200	32,700	54,600	12,250	90,400T	32,700	34,800	26,720
Waterwall, make	...	...	...	C. E.	C. E.	C. E.	...	...
Area, sq ft	...	...	...	3063	12,260	8008	...	...
Furnace-bottom type	Wet, continuous	Wet, continuous	Dry	Chain-grate	Dry	Wet	Wet, intermittent	Dry

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NOTES:
a = Reheater Elesco, 5700 sq ft; *b* Uses boilers installed for 1—31,500 kw and 1—25,000 kw, 400-lb units; G. E. = General Electric; West. = Westinghouse; A.-C. = Allis-Chalmers; B. & W. = Babcock & Wilcox; C. E. = Combustion Engineering; F. W. = Foster-Wheeler; Ljung. = Ljungstrom.

Of course, service demand availability is affected by the number of turbines on the system, as outages are permitted when there is no demand.

Unit capacity factors are a function of system requirements and not subject to comparative analysis. However, lest it be thought that some of the high service demand availability figures given in Tables 3 and 4 were the result of scheduling outages during periods when there was no demand for the units so that such outages were not chargeable to service demand availability, Table 5 is presented. (See Tables 3 and 4 for explanation of factors.)

A unit operation factor of 96 per cent means that the unit was in service 8410 hours out of 8760. As shown in Table 5, even with unit operation factors of 96 per cent or higher, the turbine availability was 96 per cent or more when needed for service. The records cover a four- or five-year period to show that high availabilities were not secured at the expense of delayed inspection periods, and that availabilities and operating factors of 96 per cent can be maintained for a number of consecutive years.

As for boiler availability, the figure of 96.2 per cent averaged over four years for three Lakeside boilers has already been mentioned. From the experience of the American Gas and Electric Company, it is believed that better than 90 per cent can be attained regularly with 1400-lb boilers.

A superposed installation can therefore be considered to have an availability of 0.95 × 0.90 or 85.5 per cent. There is little doubt but that this might be improved to 90 per cent by coincident boiler and turbine outages as the longest back-pressure-turbine outage is chargeable to annual inspection.

With availabilities as given in Table 5, there seems little need of duplicate high-pressure boilers or turbines on an interconnected system, especially those systems that maintain spinning reserve equal to or greater than the capacity of the superposition or the largest unit. This is particularly true in cases where low-pressure boilers are available for the low-pressure turbines, making it possible to remove the high-pressure equipment from service during the periods when a large amount of surplus capacity is available.

Having obtained an estimated plant availability, the optimum output is the product of capacity, hours per year, and availability. To estimate the actual output is more complex and requires some idea of incremental costs, system characteristics, and load forecasting. This, of course, is not peculiar to superposition but applies to any method of rehabilitation or addition of capacity. It is too easy to be over-optimistic in estimating the capacity factor over the useful life of the plant in order to justify a superposition or any other improvement. In Table 1, high-pressure plant-capacity factors ranging from 55 to 75.5 per cent are shown for 1934.

INCREMENTAL COSTS

Where several stations are on the system, any of the possible changes—superposition, rehabilitation of existing units, extension similar to existing stations, or a new station—causes a change in the incremental costs of the station being studied. It then becomes necessary to estimate the load shifts between the stations resulting from the change in incremental costs, and to estimate new outputs in each station to determine the true savings. These include a study of production costs and load factors. This portion of the work is probably the most complicated of all, as may be appreciated by referring to the litera-

TABLE 3 TURBOGENERATOR AVAILABILITY, 500–1000 LB PER SQ IN.

(Figures taken from N.E.L.A. Turbines Reports, August, 1931, August, 1930, August, 1929, and July, 1927)

	550 to 1000 lb gage				1000 lb gage or above
	1930	1929	1928	1925	1930
Turbine units reviewed	17	17	12	7	10
Average capacity of units, kw	58,294	64,880	56,700	...	10,056
Service demand factor, per cent	84.40	86.05	86.70	75.39	86.87
Service demand availability factor, per cent	95.81	96.90	94.90	90.93	82.68
Unit capacity factor, per cent	57.42	60.66	65.50	39.80	51.28
Unit output factor, per cent	71.01	68.75	73.90	58.40	71.39
Service hours factor, per cent	80.87	83.34	82.40	68.10	71.82
Total outage factor, per cent	10.71	12.24	11.73	24.67	19.75
Turbine outage factor, per cent	4.32	4.76	5.60	14.75	10.68
Generator outage factor, per cent	1.21	1.17	0.54	3.72	0.48
Condenser outage factor, per cent	4.52	4.48	5.02	1.891	.....
Other causes outage factor, per cent	0.66	1.83	0.57	4.235	8.59
Reserve hours factor, per cent	8.42	4.42	5.87	7.23	8.43

NOTES:
Service demand factor = Ratio of demand hours to hours per year.
Unit output factor = Ratio of kilowatthours generated to product of unit rating and service hours.

TABLE 4 TURBOGENERATOR AVAILABILITY OF HIGH-PRESSURE UNITS AROUND 1200 LB

(Figures from E.E.I. and N.E.L.A. Turbines Reports, July, 1932; August, 1933; June, 1934)

		Factors, per cent								
Size, kw	Year	Unit capacity	Service demand availability	Unit operation	Turbine outage	Generator outage	Condenser outage	Other causes	Reserve	Inspection hr
10,000	1935	29.30	94.00	33.93	6.60	0	0	0.67	58.80	0
	1933	13.83	100.00	15.37	1.67	0	0	1.55	81.41	0
	1931	25.28	87.97	31.63	18.35	0	0	0	55.02	..
50,000	1935	11.50	94.60	94.60	5.10	0.10	0	0.10	0.10	450
	1933	14.00	100.00	79.57	15.97	0	4.46	0	0	1394
	1932	15.42	90.65	90.65	0.18	3.55	0	5.62	0	0
50,000	1935	11.90	97.50	97.50	2.10	0.10	0	0.10	0.20	192
	1933	14.72	100.00	85.36	14.37	0	0.27	0	0	1256
	1932	15.13	88.45	88.45	0	5.48	0	6.07	0	0
12,000	1933	26.31	62.29	62.29	24.72	0	0	9.44	3.55	814
	1932	21.21	70.50	47.74	5.71	0	0	36.04	10.61	0
3,360	1935	29.20	54.40	49.50	10.70	0	0	30.80	9.00	937
	1933	30.30	59.08	47.31	6.29	0	0	28.86	17.54	551
	1931	34.73	64.88	58.26	0.05	0	0	35.80	5.89	...
12,500	1935	48.20	94.40	86.00	8.30	0	0	2.00	3.70	578
	1933	55.80	92.95	81.43	4.85	0	0	1.79	11.93	0
	1931	41.04	99.14	70.21	20.11	0	0	0.45	9.23	...
7,700	1933	57.05	98.35	72.48	2.37	0	0	0	25.15	204
	1932	55.82	99.10	68.33	1.29	0	0	0	30.38	0
	1931	59.62	97.57	66.64	5.90	2.40	0	0	25.06	...
7,700	1933	58.07	100.00	72.78	0.07	0	0	0	27.15	0
	1932	48.08	97.40	61.00	1.46	0	0	2.66	34.88	0
	1931	58.20	93.35	69.34	8.40	0	0	0	22.26	0
7,700	1933	61.13	100.00	75.85	0	0	0	0	24.15	0
	1932	59.75	98.50	74.52	3.28	0	0	0	22.20	288
	1931	55.51	94.97	64.96	10.20	0	0	0	24.84	...
7,700	1933	61.67	98.83	76.98	0	1.19	0	0	21.83	0
	1932	56.10	98.00	71.95	4.11	0	0	0	23.94	0
	1931	58.52	95.38	69.36	3.20	0	0	3.0	24.44	...
10,000	1935	81.00	94.00	94.00	2.50	1.00	0	2.50	0	0
	1933	70.68	87.49	87.42	7.03	0.21	0	5.27	0	597
	1931	48.81	67.12	67.12	28.11	3.74	0	1.03	0	...
12,000	1935	100.28	99.26	99.26	0.39	0.35	0	0	0	62
	1933	76.95	93.01	93.01	2.37	0	0	4.62	0	0
	1932	54.13	70.79	70.80	24.36	0.09	0	4.75	0	0
12,500	1935	91.99	96.82	96.82	2.84	0.00	0.27	0	0	226
	1934	89.80	97.30	97.00	0.02	0.01	0	0.01	0	171
	1933	77.25	94.48	94.48	5.40	0.12	0	0	0	377
	1932	64.54	97.30	97.30	2.45	0.16	0	0.09	0	213
	1931	71.38	97.14	97.14	2.50	0	0	0.35	0	...
11,000	1935	88.56	96.57	96.16	3.41	0	0	0	0.41	269
	1934	89.00	97.00	94.00	2.90	0	0	0.03	2.13	236
	1933	84.20	94.25	89.50	6.55	0.07	0	0.52	3.36	438
	1932	83.08	94.40	91.20	3.83	0	1.29	0.43	3.25	266
	1931	79.00	93.40	92.43	6.40	0	0	0.26	0.91	...
11,000	1935	95.96	96.96	96.88	3.03	0	0	0	0.07	246
	1934	93.40	96.40	94.00	3.14	0	0	0.26	2.00	261
	1933	88.32	95.05	90.37	5.01	0.03	0	0.81	3.78	354
	1932	86.40	95.40	91.54	4.00	0.26	0.16	0.19	3.85	228
	1931	71.27	78.98	78.18	20.60	0	0	0.22	1.00	...
11,800	1935	68.95	90.03	90.03	4.00	0.43	0	0	5.54	200
	1932	46.32	77.80	77.78	0.49	0.03	0	0	21.70	0
	1931	65.65	95.43	93.39	4.44	0	0	0.03	2.14	...
Yearly averages, grouped by years										
16,847	1935	57.76	89.75	83.60	5.63	0.16	0.07	3.85	6.69	...
15,544	1933	52.69	91.72	74.95	6.44	0.11	0.32	3.52	14.66	...
17,425	1932	50.49	88.36	77.60	4.26	0.80	0.12	4.65	12.57	...
9,413	1931	55.58	88.78	71.55	10.28	0.51	0	3.43	14.23	...

NOTES:
Unit capacity factor = Ratio of kilowatthours generated to product of unit rating and total hours in a year.
Service demand availability factor = Ratio of service hours to demand hours.
Unit operation factor = Ratio of service hours to demand hours.

ture on incremental costs. It should be kept in mind that the savings made by a superposed unit is *not* the difference between the old and new costs for that station, but may lie between the costs of another station and the new superposed installation if load has been shifted from the other station to the superposed station. This subject is a field in itself and reference must be made to published studies of incremental costs.[1]

Transfer of load from an old plant to a new plant means for the former a lower capacity factor and usually poorer performance. The savings of the new plant must take this into account; in fact, the effect on the whole system must be considered. The output that the superposition can produce is only the output of the old plant plus the output that can be *economically* diverted from other plants or that can be obtained otherwise.

Thus, a tabulation may be prepared for stations A, B, and C showing:

	Before superposing				After superposing			
Station	A	B	C	Total	A	B	C	Total
Yearly output, kwhr	L	M	N	...	L + M + N	M − M	N − N	...
Production cost, mills per kwhr	.	.	.	...	....	..	..	...
Savings (difference between before and after) mills per kwhr	.	.	.	...	....	..	..	...
Yearly savings, dollars	.	.	.	...	....	..	..	...
Investment carried, dollars	.	.	.	...	....	..	..	...
Return, per cent	.	.	.	...	....	..	..	...

FUEL COSTS AND CYCLE DEVELOPMENT

The fuel cost of the station is a function of the cost per ton (for coal), the method of loading, determined as mentioned under "incremental costs," and the cycle. In developing the cycle the engineer has ample opportunity for the exercise of ingenuity.

Logan has a typical 260-lb low-pressure station cycle of the type most suitable for superposition as is illustrated by Fig. 5.

In such a station, built around 1920, there is seldom any bleeding, the only heating being done in an open heater, which does some deaerating, and which is supplied by steam-driven auxiliaries such as exciters, boiler feed pumps, and perhaps forced- or induced-draft fans.

The first step in developing a superposition cycle for such a station would naturally be to maintain the old pressure and make some changes in the turbine, if possible, to extract some steam for the deaerator, as the old turbine-driven auxiliaries would normally be out of service. Perhaps a first-stage bleed point could be applied to the turbine for an intermediate heater, and there would naturally be a crossover heater, as in Fig. 6. Note that 28,000 kw of high-pressure capacity may be superposed by this method on 50,000 kw of low-pressure capacity, so that the high-pressure unit is only 56 per cent of the existing low-pressure capacity.

The second step, Fig. 7, may be to install a 1250-lb turbine for the boiler feed pump and to obtain the steam supply for the deaerator by using turbine-driven induced-draft fans. At Logan, the amount of third-stage bleed is restricted, so that it would be impossible to heat the condensate at this point sufficiently.

The boiler-feed-pump turbine would exhaust at about 90 lb abs because so much auxiliary steam is passed into the deaerator from the induced-draft-fan turbines. This increases the capacity of the high-pressure unit to 30,000 kw on 50,000 kw of low-pressure capacity, or a ratio of 60 per cent.

The third step in this cycle would be to use the combination shown by Fig. 8, in which the pressure on the low-pressure turbines has been dropped from 250 to 200 lb, permitting a 40,000-kw high-pressure unit on 50,000-kw low-pressure capacity, or a ratio of 80 per cent. To do this at Logan required new first-stage nozzles and wheels for the low-pressure turbines.

The fourth step is shown in Fig. 9 in which 45,000 kw is superimposed on 50,000 kw of low-pressure capacity, or a ratio of 90 per cent of high-pressure capacity to low-pressure capacity. The old station with the cycle shown by Fig. 5 had a heat rate of 23,000 Btu per net kwhr, whereas this cycle has a heat rate of 12,600 Btu with 3 in. Hg condenser back pressure.

DISCUSSION OF THE CYCLE

Boiler-Feed-Pump Turbine Drives. In order that the cycle may absorb heat as efficiently as possible the boiler-feed-pump turbines must exhaust into condensers, using as cold condensate as possible. Because the generator air coolers and steam-jet air ejectors should be as close as possible to the main condensers, the best position for the boiler-feed-pump-turbine condensers is immediately after the steam-jet air pumps. This arrangement proved to be much better for the Logan plant than that shown in Fig. 7 where the boiler-feed-pump turbines exhaust at about 90 lb abs. Each of the two pumps may have its own condenser for reasons of reliability. The back pressure against these turbines will range from only 2 to 8 lb per sq in. abs. If these turbines exhausted into the deaerator, the steam consumption would be so high that the feedwater system probably could not absorb the heat together with the exhaust steam from the induced-draft-fan turbines.

Gland-Steam Leak-Off Condenser. There is probably no other place in which to save the steam from the shaft packings of the high-pressure unit than in a gland-steam condenser. All low-pressure turbines pipe back the gland-steam leak-off to a stage in the turbine that is always under vacuum. If the cycle cannot absorb the heat from the gland leak-offs of the low-pressure turbine, they may be left to discharge to the vacuum stage. This, as a rule, is inefficient, because leak-off steam passes through only one or two turbine stages, losing only 40 to 60 Btu per lb; the remainder is lost to the main condensers. If this leak-off is passed to the gland-steam condenser, approximately 1200 Btu per lb is returned in the cycle; therefore it is usually best to pipe the leak-offs from the low-pressure turbine to the new gland-steam condenser. Incidentally, this condenser may be used to bleed from the third stage of the turbine in order to control, to some extent, the deaerator pressure. This condenser also affords a convenient means for returning to the cycle such of the low-pressure drips as it is worthwhile to save.

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[1] "Economic Loading of Generating Stations," by E. C. M. Stahl, *Electrical Engineering*, September, 1931, p. 722.
"Incremental Loading of Generating Stations," by M. J. Steinberg and T. H. Smith, *Ibid.*, October, 1933, p. 674.
"The Theory of Incremental Rates and Their Practical Application to Load Division," by M. J. Steinberg and T. H. Smith, *Ibid.*, March and April, 1934, pp. 432 and 571.
"Load Division in Interconnections," by E. C. M. Stahl, *Electrical World*, March 1, 1930, p. 434.
"Hydro-Steam Combinations," by N. E. Funk, *Ibid.*, June 28, 1930, p. 1343.
"Economical Load Allocations," by Herbert Estrada, *Ibid.*, Oct. 11, 1930.
"Determining Tie Line Losses," by H. Estrada and H. A. Dryar, *Ibid.*, Oct. 24, 1931, p. 745.
"Calculating Savings From Power Interchange," by E. C. Brown, *Ibid.*, Feb. 20, 1932, p. 367.
"Dividing Hydro Load to Obtain Maximum Efficiency," by A. W. Reid, *Power*, May 24, 1932, p. 770.
"Program Load Control Improves Steam Economy," by A. P. Hayward and R. Decamp, *Ibid.*, November, 1932, p. 238.
"The Division of Load Among Generating Units for Minimum Cost," by J. E. Mulligan, Trans. A.S.M.E., vol. 57, 1935, paper FSP-57-6, p. 123.
"Apportionment of Load Among Dissimilar Units," Bulletin, Edison Electric Institute, October and November, 1935.

Deaerator. Condensers built before 1920 or shortly thereafter were seldom properly developed and arranged for efficient deaeration. It is, therefore, practically mandatory to install a deaerator because of the high cost of revamping old condensers to deaerate feedwater properly for a 1325-lb, 925-F boiler.

In planning the cycle, it is well to remember the following points affecting the deaerator:

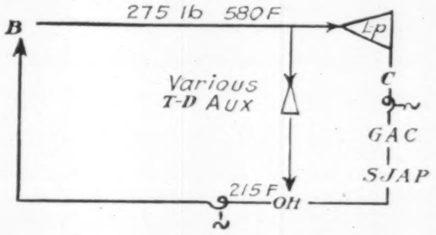

FIG. 5 TYPICAL OLD 260-LB PLANT

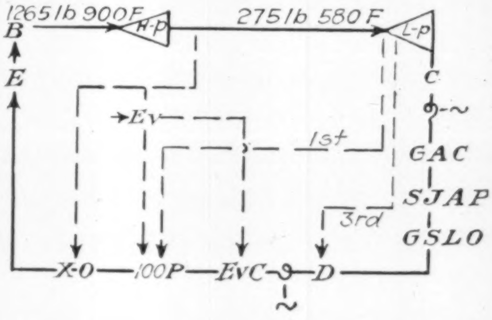

FIG. 6 SIMPLE SUPERPOSITION CYCLE—H-P: L-P RATIO = 0.56

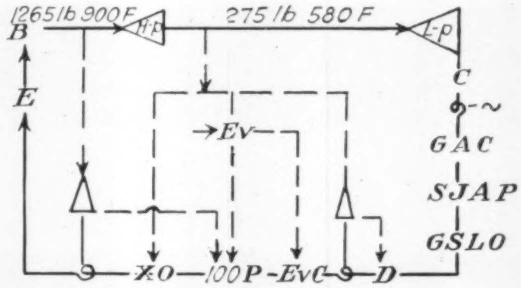

FIG. 7 SECOND STEP—H-P: L-P RATIO = 0.60

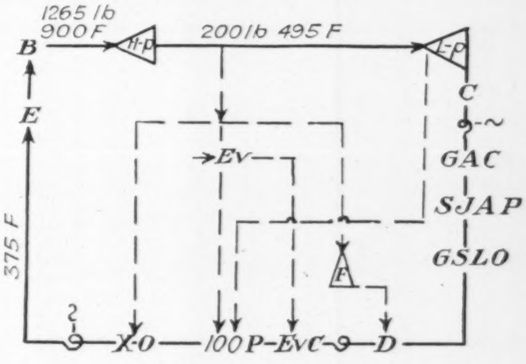

FIG. 8 THIRD STEP—H-P: L-P RATIO = 0.80

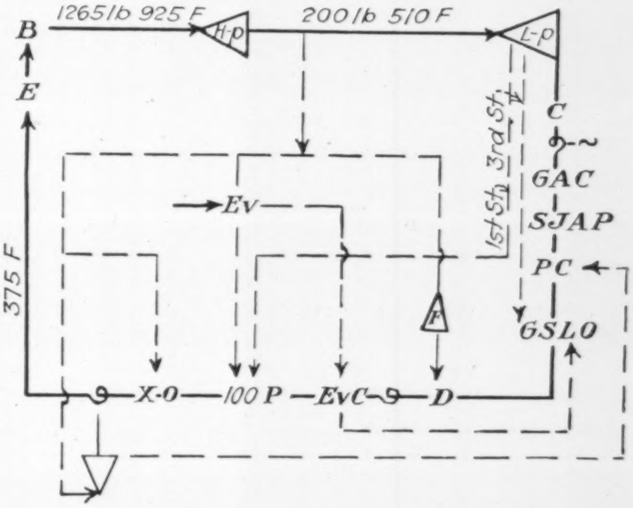

FIG. 9 MAXIMUM H-P: L-P RATIO = 0.90

(H-P = high-pressure turbine; L-P = low-pressure turbine; SJAP = steam-jet air pump; PC = boiler-feed-pump turbine condenser; GSLO = gland steam leak-off; D = deaerator; Ev, EvC = evaporator, evaporator condenser; 100 P = 100-lb first-stage heater; X-O = crossover heater; E = economizer; B = boiler; P = absolute pressure; F = fan turbine; C = condenser.)

1 Keep the deaerator under positive pressure at all loads to avoid air infiltration through the piping, large deaerator joints, and equipment under vacuum; to avoid cost and complication of a steam-jet air ejector and its vent condenser; to avoid the necessity of a flash-type deaerator which may cause a cycle heat loss; and to avoid the cost of a large vent condenser. Maintaining positive pressure may be difficult at partial loads when using an uncontrolled turbine bleed point as the source of deaerating steam supply necessitating other sources of steam supply.

2 Avoid a pressure in excess of 30 lb gage because of A.S.M.E. code restrictions above that pressure and higher cost. It may also become necessary to use a float-controlled overflow valve which is not as satisfactory as a loop seal.

3 It is desirable to have a temperature rise of 30 F or more through the deaerator. As induced-draft fan power varies approximately as the cube of the boiler steam output, it is necessary to have an auxiliary source of steam supply for partial-load conditions.

Tank Pumps. The location in the cycle of the boiler feed pump is a matter of debate. Some of the advantages of placing these pumps immediately after the deaerator are:

1 The pumps would handle the coldest water possible which some believe should decrease maintenance and trouble with the boiler feed pump.

2 Less power is used in pumping cold water than in pumping hot water. This may amount to 400 hp for a 50,000-kw superposition installation.

3 Possibly fewer pumps may be required.

Against these advantages are those of using tank pumps and placing the boiler feed pumps after the cross-over heater:

TABLE 5 TURBOGENERATOR AVAILABILITY

	Factors, per cent								
Year	Unit capacity	Service demand availability	Unit operation	Turbine outage	Generator outage	Condenser outage	Other cause outage	Reserve	Hours inspection
	50,000-kw, 600-lb, 725-F, single-element, reheat, condensing unit								
1931	89.44	95.56	96.38	2.84	0.30	0.25	0.02	0.21	Yes
1932	86.49	96.21	96.24	1.91	0.15	0.30	0.84	0.56	182
1933	88.35	97.05	97.05	2.16	0.25	0.18	0.07	0.29	177
1934	90.85	97.64	97.64	1.71	0.29	0.06	0.00	0.31	158
1935	88.74	97.61	97.61	1.47	0.31	0.07	0.22	0.22	151
	50,000-kw, 600-lb, 725-F, single-element, reheat, condensing unit								
1931	91.65	96.87	96.71	2.24	0.37	0.11	0.23	0.33	Yes
1932	89.49	97.47	97.47	1.67	0.16	0.38	0.03	0.29	155
1933	86.60	95.50	95.40	3.72	0.40	0.16	0.10	0.22	355
1934	92.88	99.33	99.14	0.00	0.29	0.19	0.11	0.28	0
1935	90.25	96.70	96.60	2.36	0.29	0.19	0.13	0.41	162
	11,000-kw, 1200-lb, 725-F, cross-compounded with following 42,000-kw element								
1932	83.08	94.40	91.20	3.83	0.00	1.29	0.43	3.25	266
1933	84.20	94.25	89.50	6.55	0.07	0.00	0.52	3.36	438
1934	89.00	97.00	94.00	2.90	0.00	0.00	0.03	2.13	236
1935	88.56	96.57	96.16	3.41	0.00	0.00	0.00	0.41	269
	42,000-kw, 350-lb, 750-F, reheat, cross-compounded with above 11,000-kw turbine								
1932	81.98	95.00	91.50	3.26	0.00	1.29	0.44	3.51	212
1933	81.93	94.90	90.12	4.91	0.07	0.69	0.16	4.07	420
1934	99.00	97.10	95.00	2.73	0.00	0.00	0.03	2.21	236
1935	90.37	97.10	96.54	2.88	0.00	0.00	0.00	0.56	248
	11,000-kw, 1200-lb, 725-F, cross-compounded with following 42,000-kw element								
1932	86.40	95.40	91.54	4.00	0.26	0.16	0.19	3.85	228
1933	88.32	95.05	90.37	5.01	0.03	0.00	0.81	3.78	354
1934	93.40	96.40	94.00	3.14	0.00	0.00	0.26	2.00	261
1935	95.96	96.96	96.88	3.03	0.00	0.00	0.00	0.07	246
	42,000-kw, 350-lb, 750-F, reheat, cross-compounded with above 11,000-kw turbine								
1932	79.80	95.40	91.54	4.00	0.26	0.16	0.19	3.85	228
1933	81.87	95.70	90.91	4.18	0.12	0.27	0.14	4.38	362
1934	94.00	96.70	94.00	3.00	0.00	0.00	0.10	2.40	261
1935	90.74	97.06	96.88	2.87	0.00	0.00	0.00	0.18	246

1 Certain evidence indicates that difficulties with high-pressure boiler feed pumps have been a function of temperature variations rather than high temperature. By placing boiler feed pumps after the crossover heater, the temperature of the water handled by the boiler feed pumps is uniform, attaining a maximum variation of plus or minus 8 F from no load to full load, because of the back-pressure control on the superposed unit. There is reason to believe that, under such arrangement, there will be no more trouble with the pumps than if they handled cold water.

2 In a plant where coal costs are high, it is possible that there is justification for saving some 400 hp in the boiler feed pumps. However, in a station where coal costs are less than $2 per ton, the cost of such auxiliary power is relatively insignificant.

It may be questioned why an attempt was made earlier to justify saving 450 kw in the generator by hydrogen cooling when at the boiler feed pumps it appears negligible. In the case of the generator, the saving of 450 kw is made only incidentally to the necessity of using hydrogen cooling for large 3600-rpm units. Furthermore, the investment cost of hydrogen cooling of certain units is no more than for air cooling. This is particularly true in cases where condensing-water temperatures are high, making the installation of generator air coolers using condensate economically unjustifiable. In such cases, it is better to waste such heat by using river water for the air coolers.

On the other hand, if turbine-driven boiler feed pumps that exhaust into feedwater heaters are used, the exhaust heat is returned to the system, the only loss being the kilowatthours that would have been generated by the main units if the equivalent amount of heat had been extracted from bleed points.

3 If it is necessary at times to run low-pressure turbines, when the high-pressure boiler is out of service, the tank pumps are required in any event for supplying existing low-pressure boilers.

4 By using tank pumps, only 300-lb heaters need be installed, whereas if the boiler feed pumps are placed after the deaerator, it is necessary to purchase heaters for 1600 lb water pressure. Such heaters would cost approximately double those for 300 lb.

Under other conditions it may be necessary or desirable to install two sets of bleed heaters in parallel. In this case, when one set of heaters is out of service and all the feed is passing through the other with attendant higher pressure drop, or when extra high ratings or other conditions demand a pressure higher than normal from the boiler feed pumps, the booster pump immediately before the boiler feed pump is used to create the needed additional head.

Evaporator. Experience has shown that only a 2 per cent make-up evaporator should be necessary. The drips from the evaporator condenser should be piped into the system so that the drips will enter the deaerator with the regular condensate flow. The deaerator should not be used as an evaporator condenser because of the difficulty in removing the air from the vapor, as against removing air which is dissolved in the feedwater going to the deaerator.

100-Lb Heater. If a 100-lb heater were not installed, an uneconomical jump would be made from 250 F to 378 F. Not only this, the size of the crossover heater would be so large as perhaps to make advisable the installation of two crossover heaters instead of one. Moreover, the installation of a 100-lb heater permits some 3000 kw to be obtained practically free of fuel cost, as this bleed steam passes through the first stage of the low-pressure machine instead of being taken from the crossover line.

Crossover Heater. It is advisable under all circumstances to install a crossover heater, as there is no doubt that the installation is justifiable.

400-Lb Heater. There is some question as to whether a 400-lb heater can be justified. In the case of Logan, a 400-lb bleed point was provided on the 40,000-kw turbine for possible future use.

General. Consideration should be given to the installation of a duplicate set of half-size heaters, so that either set can be removed from service, evaluating the advantages against a single set of full-size heaters with their by-passes. No generalization can be made on this because of the influence of local factors peculiar to the individual plant.

Rather than return the balancing-drum leakage from the boiler feed pumps immediately to their suctions, it should be carried to a point where it may be cooled or mixed with cooler

(*Continued on p. 584*)

Design Trends in 500-800 LB STEAM PLANTS

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THE DESIGN of a steam-electricgenerating plant is probably influenced by more factors today than at any time in history. Every plant has always had its peculiar problems and influences, such as the price and type of fuel, load factor, condensing-water facilities, and foundations; but today, certain social, political, and economic influences, common to all plants, must be recognized by the design engineer.

GENERAL INFLUENCES

There is a definite demand by the public for lower electric rates. This demand has been influenced by governmental activities in attempting to create "yardsticks" for the electric-utility industry by means of projects which do not include all the elements of cost incurred when the industry is financed by private capital. The public is also becoming more critical both of noise and the ash nuisance; and the use of special equipment to avoid such complaints is adding to the first cost of the plant.

Loss of load during the first years of the depression caused curtailment of the construction of plants, with the result that engineering organizations and manufacturers found it necessary to reduce their personnel. With the load now rapidly growing, much new construction is to be expected in the utility systems, and with the reduced personnel it will be impossible to construct plants in the immediate future as rapidly as before the depression, because of the necessity of rebuilding these organizations both for design and for manufacture. The consequent long deliveries for major equipment will require that, from the authorization of a project until operation is begun, at least six months more must be allowed than was the case in the past.

Uncertainty in the electric industry as a result of legislation, governmental competition, rate reductions, difficulties in financing, and other disturbing influences have delayed the execution of plans for future expansion until the last minute. Such delay makes it difficult to have the additional plant capacity ready for service when required, particularly with the increasingly long delivery time now in prospect for major equipment.

Within the last ten years fuel consumption has been constantly reduced with little increase in first cost per kilowatt of plant capacity. Reductions in fuel consumption have been made possible by the use of higher steam pressures and temperatures, which have progressed in steps. The first installation at each step has naturally been more costly than subsequent installations because of development expense required of the owner and manufacturer.

Utilities have led this development because, with growing loads, new installations have become the primary units of the systems, while the less efficient equipment previously installed has become secondary in sequence of operation. It would have been impossible for industrial plants to have contributed the same development because of their relatively constant demand for electricity and steam and their much lower rate of expansion of power service.

Experience with plants constructed for a steam pressure of 1400 lb has been acquired, and some data are available on materials subjected to steam temperatures up to 1000 F. It appears advisable at this time, therefore, to inventory such designs and the operating experiences and economics of plants already constructed, as well as present-day influences, so as to determine the trend of power-station design from the standpoint of efficiency and fixed charges, with a view to the utilization of equipment, already more or less developed, to the end that the outlay of money for the construction of new plants may be at a minimum to obtain the lowest overall cost of energy at the bus bar.

It is not expected that the fuel consumption will be materially reduced below that of plants already in operation, and as the yearly fixed charges per kilowatt on the plant are greater than the cost of fuel, it is to be expected that fixed charges will henceforth carry even more weight than formerly in the mind of the designing engineer.

TRENDS OF EQUIPMENT COST

Fig. 1 shows the average cost of turbines and condensers from 1915 to 1935, inclusive. These data are based on the average sales price of turbines and condensers during the period indicated. During these years considerable change in design and materials used produced more efficient and more reliable apparatus, which naturally increased the unit cost of equipment. No data are available for detailed comments on these gradual increments of cost.

Fig. 2 shows the average cost of boiler installations from 1915 to 1935, inclusive. During this period steam pressures have greatly increased. However, this change has been accomplished with improved construction and greater reliability and with small increase in cost of boiler equipment. Data showing the first cost of equipment per pound of steam for various pressures, would be extremely interesting, but such data are not available.

SCOPE OF DISCUSSION

The following discussion relates entirely to plants of the condensing type with turbine units of from 5000 to 25,000 kw operating at 3600 rpm and boiler pressures of from 500 to 800 lb gage.

TURBINES

Turbogenerators cost more today per kilowatt of capacity than they have at any time in history. It is true that they are more economical and require fewer pounds of steam per kilowatt, which automatically makes a reduction in the cost of

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Contributed by the Power Division and presented at a meeting, Niagara Falls, N. Y., Sept. 17–19, 1936, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

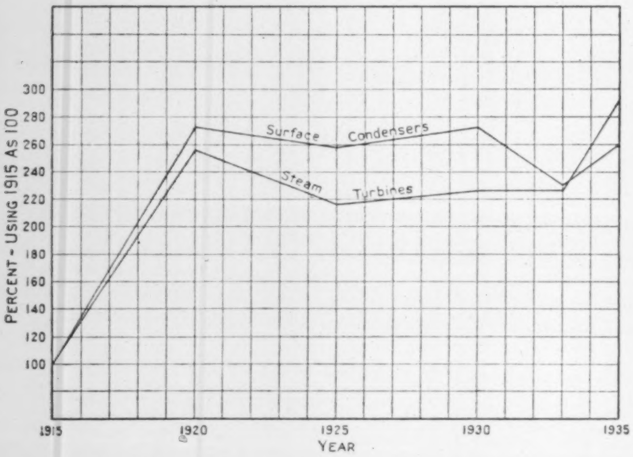

FIG. 1 RELATIVE AVERAGE COST OF TURBINES AND CONDENSERS

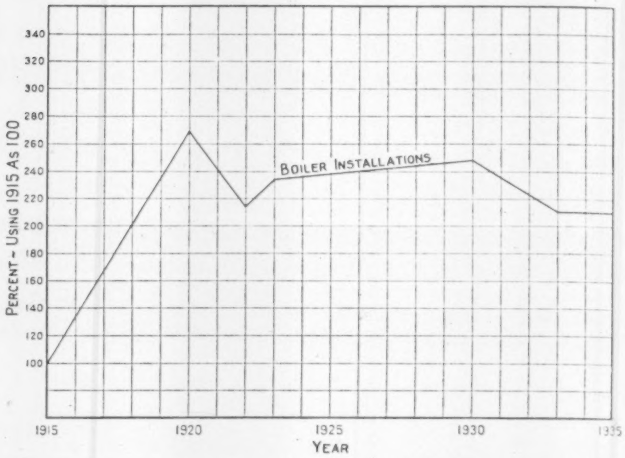

FIG. 2 RELATIVE AVERAGE COST OF BOILER INSTALLATIONS

the boiler-room equipment, and this partially offsets the increase in price of turbines.

In past years the amount of moisture in the last rows of blades has been a serious problem and has caused so much erosion as to require taking the units out of service from time to time for blade renewals. With the higher pressures and the development of better materials and designs for trapping moisture, the question of erosion does not appear to be of major consideration at this time. With present materials, turbines should operate with a higher availability factor even with a moisture content in the last rows of blades as high as 12 per cent.

Fig. 3 shows the temperature of superheated steam plotted against throttle pressure to produce 10, 11, and 12 per cent moisture in the exhaust of the turbine. These data are based on 29 in. vacuum and 80 per cent Rankine-cycle efficiency, and indicate results obtained with a modern efficient turbine. With a less efficient turbine the moisture in the exhaust would naturally be less. The minimum superheat temperature can be determined for any pressure after selecting the permissible percentage of moisture in the turbine exhaust. For example; with a throttle pressure of 650 lb and 11 per cent moisture in the exhaust, the minimum superheat temperature would be 815 F. These data indicate that the superheat is limited by conditions at the front end of the turbine and is governed by the materials used in the superheater and in the high-pressure end of the turbine.

Turbines constructed for temperatures in excess of 850 F are still in the developmental stage and if the highest availability is required, should not be generally used until several more years' experience is available.

CONDENSERS

Extremely efficient condensers from a heat-transfer viewpoint are available today, and little development in this respect is expected in the immediate future in the design of condensers. The proper size of a condenser depends, of course, upon fuel cost, the ability of the turbine to use a higher vacuum, the load factor, and the water temperature. Economic studies that take into consideration all these factors will probably indicate that there will be a reduction in surface per pound of steam because of the higher cost of condensers.

The chlorination of condensing water has permitted condenser operation at practically test conditions year in and out without hand cleaning except for removing debris from the water boxes. In one installation where considerable time would have been required for cleaning tubes to maintain satisfactory vacuum without treatment of condensing water, operation from 1929 to date has been without loss of vacuum and without cleaning of condenser tubes, as a result of the installation of chlorinating apparatus.

STEAM-GENERATING UNIT

The proper selection of a steam-generating unit requires greater consideration than any other piece of major equipment in a power plant, and today there is no such thing as a standard unit. The grouping of furnace, boiler, superheater, economizer, and air heaters should be a "tailor-made" job, as these items are affected by steam pressures and temperatures, type of fuel, price of fuel, load factor, as well as by many other factors.

The first cost per pound of steam-generating equipment has been declining even in the face of higher pressures and temperatures, and has been brought about by improved methods in manufacturing and the proper proportioning of each general subdivision of heat-absorbing surface and greater availability.

It is interesting to note the successive changes in drum design with the increase in steam pressure. For a period there was a limit in the maximum possible boiler pressure due to the construction of riveted drums. Straight-tube boilers were constructed with riveted drums for a steam pressure of 650 lb but bent tubes were limited to lower pressures. The demand for boilers for pressures in excess of 650 lb was met by the use of forged drums.

Increase in steam pressure advanced at a more rapid rate than the increase in steam temperature, and as a result the first plants built for pressures of 600 lb and above used the reheat cycle. When comparative analyses were made of 600- and 1200-lb plants, it was found that the 1200-lb plant was more economical than the 600-lb plant due to higher efficiency of the 1200-lb reheat cycle and the small increase in boiler-plant cost.

With the development of superheaters and turbines for higher steam temperatures, the simple straight-expansion plant for pressures of from 600 to 800 lb became more attractive. About the same time welded drums came into existence and brought about a decided reduction in boiler cost. These developments have practically eliminated consideration of plants of the reheat type. A plant of the single-expansion type has the advantage of simplicity of construction and operation and of lower first cost. With modern high-pressure boilers and with proper feedwater control, the availability of boiler units approaches the availability of turbines.

The continually increasing superheat has called for intense study in the design of the superheater. The design of the superheater is affected by the kind of fuel, permissible CO_2 in the furnace, type of furnace, type of boiler baffling, amount of waterwall and boiler surface ahead of the superheater, pressure loss through the superheater, and the feedwater temperature.

All of these variables make the performance of the superheater somewhat uncertain and in order to be sure to obtain guaranteed results, designers invariably plan for a surplus steam temperature. This condition is sometimes embarrassing to the turbine manufacturer during the early stages of operation before final adjustments are completed. As superheater designs progress relatively rather than by exact calculations, radical designs and large increases in superheated-steam temperatures should be avoided.

As the pressure increases it becomes necessary to increase the exit temperature from the boiler to obtain the lowest first cost for the complete boiler unit per pound of steam because of increasing saturated-steam temperature. For the most economical size of boiler, the temperature of the gases leaving the boiler should be from 200 to 250 F greater than the saturation temperature.

Fig. 4 shows the average exit flue-gas temperature from the boiler proper and the range of exit-gas temperature from the final flue-gas heat-recovery apparatus.

Heat may be absorbed from the flue gas after leaving the boiler by an economizer, an air heater, or a combination of economizer and air heater.

The equipment to be selected depends on the first cost of flue-gas recovery apparatus to obtain the justified final gas temperature, and the temperature of preheated air required for a specific fuel.

With pulverized fuel, preheated air is necessary for drying the fuel, the temperature being determined by the kind of fuel. Where it is advisable to use an economizer with pulverized coal, preheated air may be obtained by means of an air heater heated by steam bled from the turbine. The advantage of this method is controlled preheat air temperature with varying moisture content of the coal without by-passing the combustion air around the air heater and tempering for the desired preheat temperature.

DEAERATING FEEDWATER HEATERS

With higher pressures it is necessary that the boiler tubes be free not only from scale but also from corrosion. The deaerating heater thus becomes a necessary piece of equipment in any modern plant. It can best be located in the heat cycle so as to operate slightly above atmospheric pressure under all conditions of load. Any deaerating heater should consist of trays over which the water passes with sufficient steam scrubbing these trays to scavenge them and to dissolve oxygen in the incoming feedwater. The scavenge steam should be condensed by a vent condenser of a size which will give a heat pickup in the incoming water of at least 30 F. Deaerating heaters should produce boiler feedwater with an oxygen content of not more than 0.01 cc per liter.

FEEDWATER TREATMENT

An essential factor in any steam plant is proper feedwater equipment and control. The water in the boiler must be properly maintained at the correct pH value, free from corrosive agents and scale-forming solids, and at a concentration that will prevent foaming or priming in the boilers. Where necessary, steam washers should be used in the boiler to prevent excessive carry over, which is detrimental to the operation of superheaters and turbines. In the author's opinion, the first step to be taken in any new boiler plant is a study of the chemical analysis of the raw feedwater supply, including its seasonal variation. Such studies must be made prior to the selection of any major equipment as they may have a definite bearing not only on the boiler equipment but also on the heat cycle.

HEAT CYCLE

It is most desirable from the standpoint of boiler operation economical arrangement of boiler surfaces, and superheat control to have the feedwater enter the boiler at as high a temperature as possible. It appears advisable to heat the feedwater entering the boiler to within 100 F below the saturation point at maximum rating, and therefore an economizer may be justified except in cases where extremely high air preheat may be necessary.

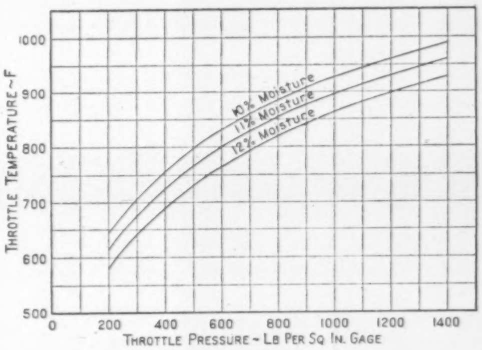

FIG. 3 MOISTURE CONTENT IN EXHAUST STEAM
(29 in. vacuum, 80 per cent Rankine-cycle efficiency.)

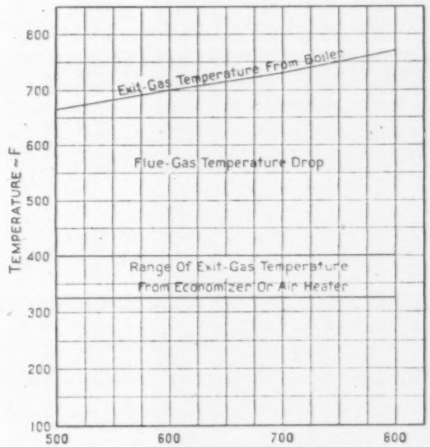

FIG. 4 FLUE-GAS TEMPERATURE

If the temperature of the condensate from the condensers is assumed to be 85 F, it is desirable to place a bleeder heater between the condensate pump and the deaerating heater. If the temperature in the deaerating heater is about 214 F, the bleeder heater should heat the water to a temperature of approximately 184 to 170 F for pressures of 500 and 800 lb, respectively. A turbine-driven boiler feed pump is always desirable and should exhaust into the deaerating heater to provide suf-

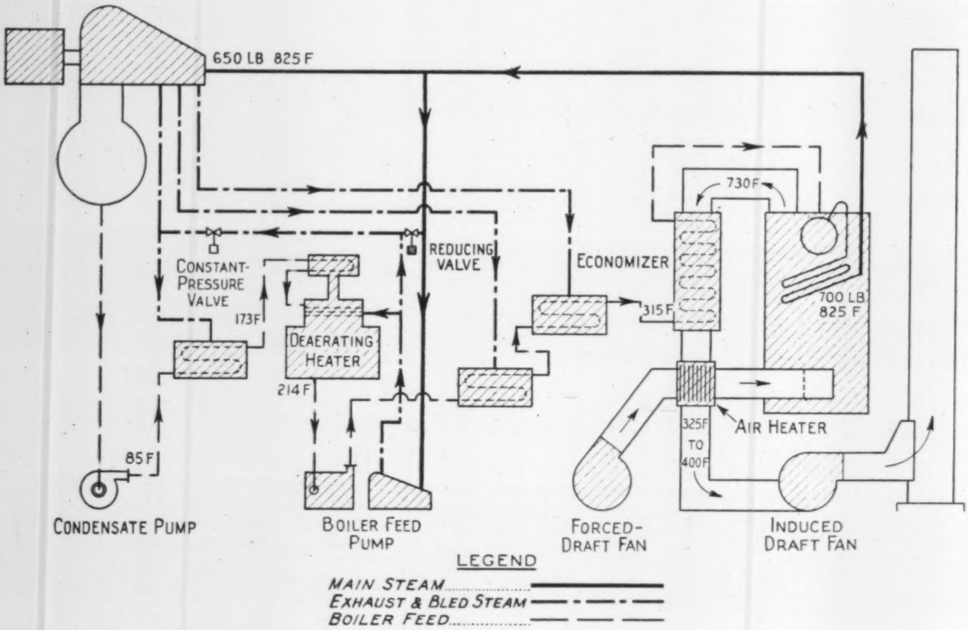

FIG. 5 FLOW DIAGRAM FOR STEAM POWER PLANTS—500–800 LB PRESSURE

ficient steam to maintain deaeration under all conditions of load. A perfect heat balance is obtained at all loads by means of the reducing valve and constant-pressure valve shown in Fig. 5. Surplus steam from the boiler feed pump spills over to the first bleeder heater and shortage of steam is made up by the reducing valve.

The use of bled steam from the turbine is an economical means of heating feedwater, as this bled steam has provided some mechanical power before entering the bleeder heaters. With higher feed temperatures, however, the amount of superheat in the bled steam increases. This condition is shown in Fig. 6. The high superheat has a tendency to reduce the use of higher heating of feedwater by bled steam and introduces a new problem in closed-heater design for superheated steam. A contact heater could be used instead of one of the closed type but it adds to the complication of the heat-cycle hook-up and requires a special boiler feed pump.

With the foregoing in mind it would appear uneconomical to install more than the two additional bleeder heaters beyond the deaerating heater and to obtain the final feedwater heating by means of an economizer.

Fig. 7 shows suggested feedwater temperatures at various boiler pressures.

PRESSURES AND TEMPERATURES

The foregoing remarks apply to pressures of from 500 to 800 lb at the boiler and 50 to 75 lb less at the turbine throttle.

It is expected that the superheated temperature range will be from 750 to 850 F, the specific temperature being governed mainly by the selection of the turbine.

Some of the statements might be slightly modified for a specific case, but the discussion has been general rather than specific for the sake of brevity.

Temperature in excess of 850 F should be considered as in the developmental stage and as applying only to compound turbines where the high temperature can be confined to the high-pressure element. The immediate use of temperatures in excess of 850 F will probably be limited to superimposed installations. When definite operating experiences with plants using temperatures of from 925 to 950 F are available and manufacturers are prepared to offer on a production basis material satisfactory for these temperatures, large compound turbine units may be used for a straight condensing cycle with pressures of from 1200 to 1300 lb at the throttle.

CONCLUSIONS

When all factors and influences are taken into consideration, it is believed that straight condensing-cycle plants of tomorrow, in moderate size (5000 to 25,000 kw) turbine units, will be built for boiler pressures between 500 and 800 lb and superheat temperatures of from 750 to 850 F.

It is believed that plants which have an average fuel cost and load factor, for a boiler pressure of approximately 700 lb and a superheat temperature of 825 F, will produce electrical energy on the bus bar at the lowest total cost per kilowatthour.

Not more than three stages of feedwater heating with an economizer will give the best feedwater heating cycle, except where extremely high air preheat is necessary.

With availability of both boiler and turbine units practically equal, one boiler unit per turbine unit should be installed in interconnected systems in plants having two units or more.

All auxiliaries except the boiler feed pump should be motor driven, with power which is supplied from station service.

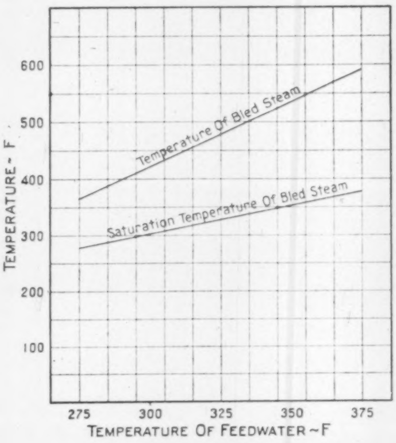

FIG. 6 SUPERHEAT IN STEAM BLED

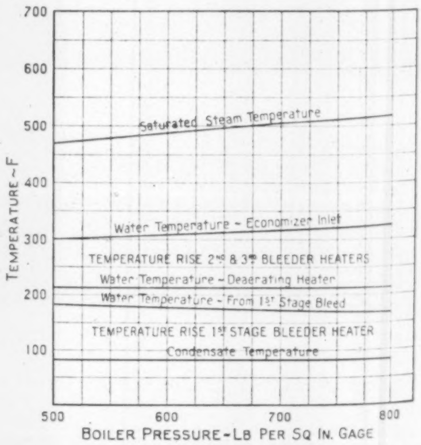

FIG. 7 STEAM AND WATER TEMPERATURES

Operating Experiences in a SUGAR-REFINERY STEAM PLANT

By DANIEL GUTLEBEN

PENNSYLVANIA SUGAR COMPANY

PROCESS changes in the "Pennsylvania" sugar refinery increased the power demand which the old 150-lb-pressure steam plant could not supply without waste of exhaust. The old boiler house was built in 1902 and extended from time to time until it consisted of 13 boilers totaling 7000 rated hp. Meanwhile refinery extensions completely hemmed in the old steam plant, leaving only a small area for coal and ash handling. In 1931 a new plant was built, and placed in operation in February, 1932.

DESIGN

The new design called for two 250,000-lb-per-hr boilers at 400 lb pressure and 50 F superheat. These are compounded upon the old plant and the mechanical-drive turbines of the auxiliaries exhaust at 150 lb into the old headers without unbalancing the existing system. Additional power is obtained through a new bleeder turbine and the remainder of the process steam not needed at present for by-product power is supplied through reducing valves.

The selection of the pressure of 400 lb and a superheat of 50 F was made without the help of mathematical analysis. At the time the plant was projected, a pressure of 200 lb could have produced sufficient by-product power. Since then a dry-ice plant has been added that requires no process steam but more than 1000 kw of power. Reductions in the cost of refining sugar are accompanied by increased power demand, but there is no means of anticipating the future needs. Processes change with remarkable speed. The old coil pans required daily $2^1/_2$ million pounds of steam at 80 lb. The conventional coil pan has been in use in all refineries for two generations. Nevertheless, a year after the installation of a turbine with an 80-lb bleeder, the coil pans suddenly became obsolete in the "Pennsylvania" refinery and were replaced with calandria pans using 10-lb or 30-lb steam.

Fig. 1 illustrates the steam distribution to the power plant and process, as well as the application of the accumulator.

DESCRIPTION

Fig. 2 shows the arrangement and the specifications of the equipment, most of which may be understood from the drawing without further explanation. All of the feed pumps, pulverizers, and blowers are driven by means of turbines receiving steam at 400 lb and exhausting at 150 lb.

Feedwater Conditioner. The water softener was designed for hot-process lime-soda operation, and has a capacity sufficient to supply about half of the steam plant while the remainder of the feedwater is supplied from process returns. Since all of the pans, evaporators, and heaters, totaling 56,000 sq ft of heating surface, are located about 90 ft above the ground, the removal of condensate is accomplished by the simple device of U-pipes. The 30-lb drips require a double U, the first being vented to the 10-lb exhaust header. Returns under pressures less than atmosphere are sealed in the flash tanks.

Coal-Handling Plant. The coal is unloaded from barges by crane or from cars by dump, delivered over a magnetic sepa-

Contributed by the Power Division for presentation at a meeting, Niagara Falls, N. Y., Sept. 17–19, 1936, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

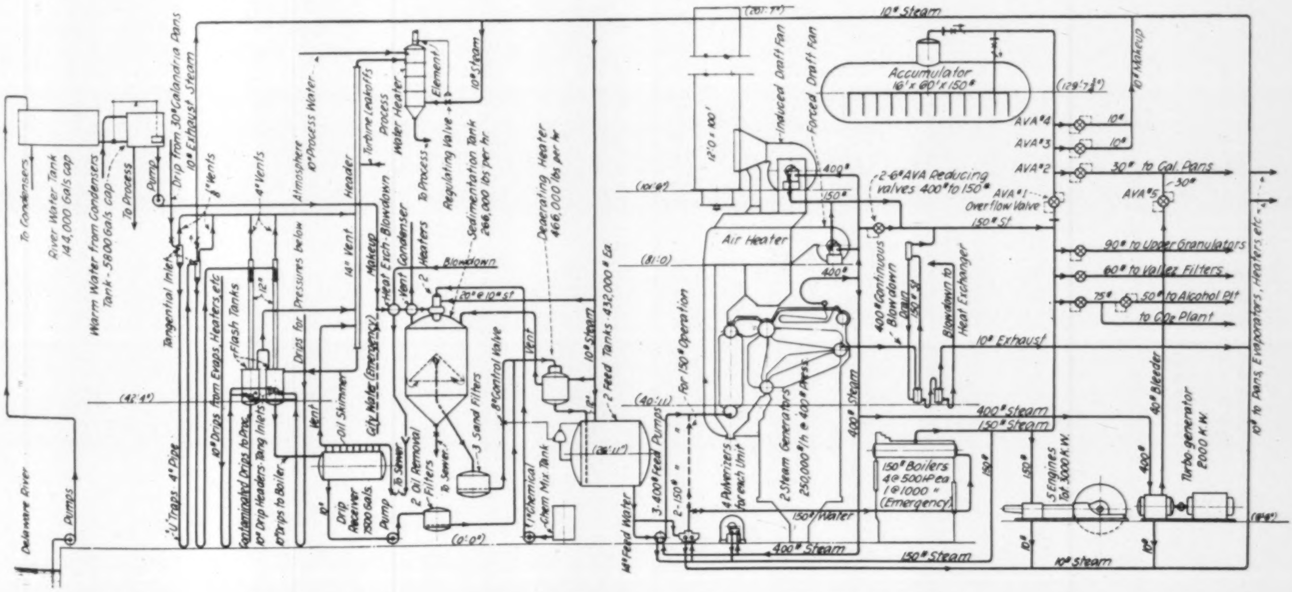
To Condensers
River Water Tank 144,000 Gals cap
Warm Water from Condensers Tank - 5800 Gals cap
To Process
Pump
Drip from 30# Calandria Pans
10# Exhaust Steam
8" Vents
4" Vents
Atmosphere
10" Process Water
Header
Turbine Leakoffs
Process Water Heater
Element
10# Steam
To Process
Regulating Valve
Sedimentation Tank 266,000 lbs per hr
Deaerating Heater 466,000 lbs per hr
Tangential Inlet
Drips from Evaps, Heaters, etc
Flash Tanks
12"
Drips for Pressures below
14" Vent
Makeup
Heat Exch. Blowdown
Vent
Condenser
Heaters
Blowdown
2
20# @ 10# St
10# Steam
2 Feed Tanks - 432,000# Ea.
(42'4")
U Traps 4" Pipe
10" Drips from Evaps, Heaters, etc
Contaminated Drips to Proc.
10" Drip Headers - Tang Inlets
10" Drips to Boiler
Vent
Oil Skimmer
City Water (Emergency)
Drip Receiver 7500 Gals
Pump
To Sewer
2 Oil Removal Filters
To Sewer
3 Sand Filters
8" Control Valve
Vent
1 Chemical Chem Mix Tank
(0'0")
Delaware River
Pumps
14" Feed Water
(201'7")
12'0 x 100'
Induced Draft Fan
Forced Draft Fan
10# Steam
Accumulator 16' x 60' x 150#
(129'7")
10" Makeup
AVA #4
AVA #3
AVA #2
AVA #1 Overflow Valve
AVA #5
10#
10#
30# to Cal. Pans
30#
(101'9")
400#
150#
2-6" AVA Reducing valves 400# to 150#
150# St
Air Heater
(81'0)
400#
90# to Upper Granulators
60# to Vallez Filters
75#
50# to Alcohol Pit
to CO2 Plant
For 150# Operation
400# Continuous Blowdown Drain
150# St
Blowdown to Heat Exchanger
10# Exhaust
(40'11")
3-400# Feed Pumps
2-150#
4 Pulverizers for each Unit
2 Steam Generators 250,000#/h @ 400# Press.
400# Steam
400# Steam
150# Steam
150# Boilers 4 @ 500HP ea. 1 @ 1000 " (Emergency)
150#
150#
5 Engines Tot. 3000 K.W.
400#
40# Bleeder
Turbo-generator 2000 K.W.
10" to Pans, Evaporators, Heaters etc.
(28'11")
150# Water
400# Steam
150# Steam
10#
10#
10# Steam

FIG. 1 DIAGRAMMATIC OUTLINE OF STEAM POWER PLANT, PENNSYLVANIA SUGAR COMPANY

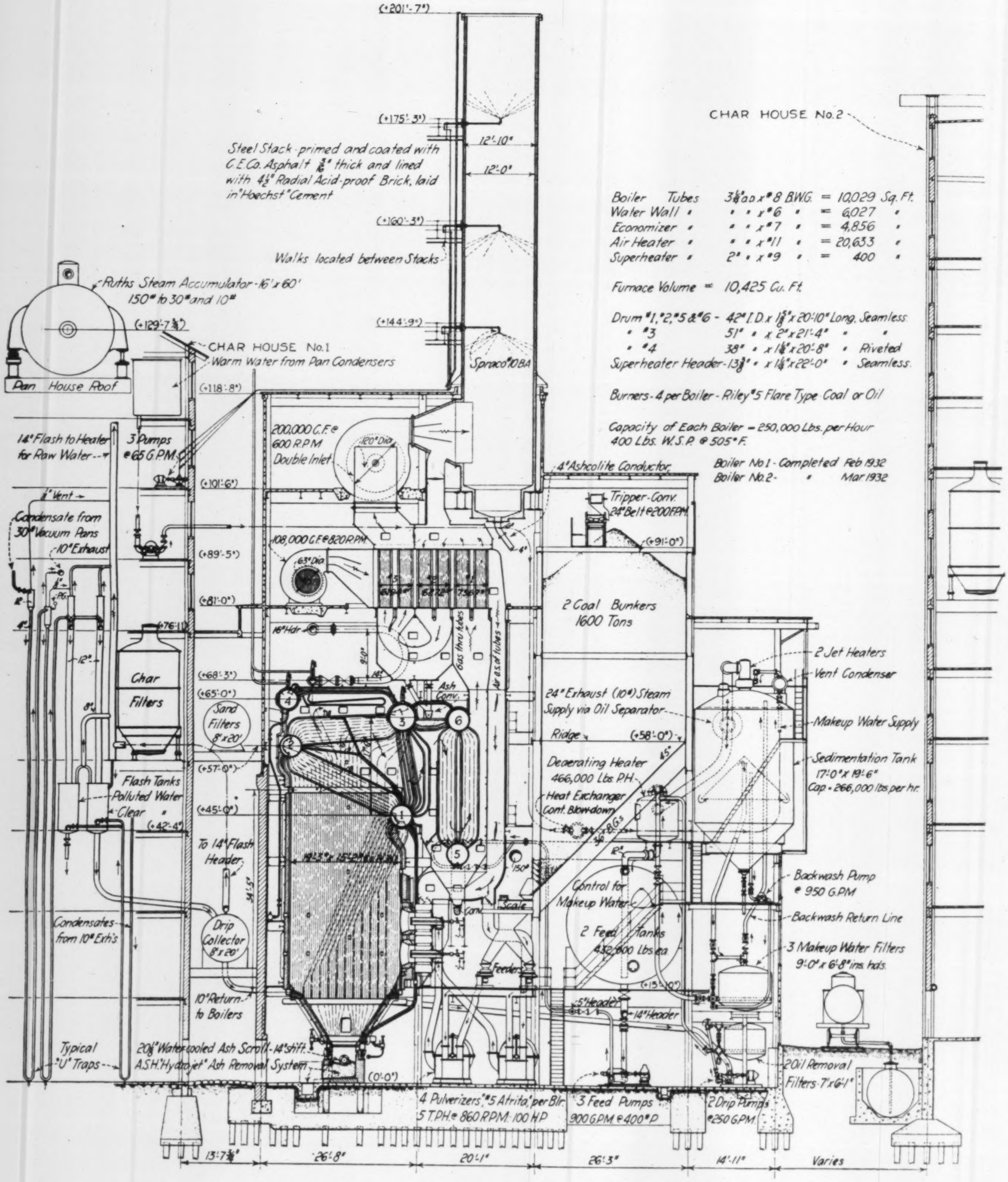
(+201'-7")
(+175'-3")
12'-10"
12'-0"
Steel Stack-primed and coated with C.E.Co. Asphalt 3/16" thick and lined with 4½" Radial Acid-proof Brick, laid in "Hoechst" Cement
(+160'-3")
Walks located between Stacks
(+144'-9")
Spraco #10BA
Ruths Steam Accumulator-16' x 60' 150# to 30# and 10#
(+129'-7¾")
CHAR HOUSE No.1
Warm Water from Pan Condensers
Pan House Roof
(+118'-8")
14" Flash to Heater for Raw Water
3 Pumps @ 65 G.P.M.
200,000 C.F.@ 600 R.P.M Double Inlet
120" Dia
(+101'-6")
2" Vent
Condensate from 30" Vacuum Pans
10" Exhaust
108,000 C.F.@ 820 R.P.M
63" Dia
(+89'-5")
(+81'-0")
16" Hdr
P.G.
12"
4"
(+76'-11")
12"
8"
Char Filters
Gas thru tubes
Air o.s. of tubes
Ash Conv.
(+68'-3")
(+65'-0")
Sand Filters 8' x 20'
(+57'-0")
(+45'-0")
Flash Tanks
Polluted Water
Clear
(+42'-4")
To 14" Flash Header
34'-5"
Drip Collector 8' x 20'
Condensates from 10" Exh's
10" Return to Boilers
Typical "U" Traps
20⅛" Water-cooled Ash Scroll-14" shft. A.S.H. "Hydrojet" Ash Removal System
(0'-0")
Scale
Feeders
150"
4 Pulverizers, "#5 Atrita," per Blr. 5 T.P.H.@ 860 R.P.M. 100 H.P.
CHAR HOUSE No.2
Boiler Tubes 3¼" o.d. x #8 B.W.G. = 10,029 Sq. Ft.
Water Wall " " " x #6 " = 6,027 "
Economizer " " " x #7 " = 4,856 "
Air Heater " " " x #11 " = 20,633 "
Superheater " 2" " x #9 " = 400 "
Furnace Volume = 10,425 Cu. Ft.
Drum #1, #2, #5 & #6 - 42" I.D. x 1⅝" x 20'-10" Long, Seamless
" #3 51" " x 2" x 21'-4" " "
" #4 38" " x 1½" x 20'-8" " Riveted
Superheater Header - 13⅜" " x 1½" x 22'-0" " Seamless
Burners - 4 per Boiler - Riley #5 Flare Type Coal or Oil
Capacity of Each Boiler - 250,000 Lbs. per Hour 400 Lbs. W.S.P. @ 505° F.
Boiler No.1 - Completed Feb. 1932
Boiler No.2 - " Mar. 1932
4" Ashcolite Conductor
Tripper-Conv. 24" Belt @ 200 F.P.M.
(+91'-0")
2 Coal Bunkers 1600 Tons
2 Jet Heaters
Vent Condenser
24" Exhaust (10#) Steam Supply via Oil Separator
Makeup Water Supply
Ridge
(+58'-0")
45°
Deaerating Heater 466,000 Lbs. P.H.
Sedimentation Tank 17'-0" x 19'-6" Cap. - 266,000 lbs per hr.
Heat Exchanger Cont. Blow-down
36" B.G.s
12"
Control for Makeup Water
Backwash Pump @ 950 G.P.M
Backwash Return Line
2 Feed Tanks 432,600 Lbs. ea.
3 Makeup Water Filters 9'-0" x 6'-8" ins. hds.
(+15'-10")
5" Header
14" Header
2 Oil Removal Filters 7' x 6'-1"
3 Feed Pumps 900 G.P.M.@ 400# P
2 Drip Pumps @ 250 G.P.M.
13'-7⅜"
26'-8"
20'-1"
26'-3"
14'-11"
Varies

FIG. 2 VERTICAL SECTION OF STEAM POWER PLANT, PENNSYLVANIA SUGAR COMPANY

rator to a crusher, thence via bucket elevator to the distributing conveyor above the bunkers. The front of the bunkers is vertical to avoid bridging. A partition divides the bunker into two pockets, one for each boiler. This permits cleaning one pocket while the other is in use. It also allows simultaneous trials of two coals. The 45-deg slope of the bottom is not sufficient to allow the coal to slide, but a wedge of dead storage remains which catches fire if not cleaned out at least every six months. However, as a guard against operating forgetfulness a CO_2 distributing system is provided with nozzles through the plate. This will extinguish any fire in a half-hour's time, using up to a dozen 50-lb bottles of CO_2. After a fire, the hopper must be allowed to run down for cleaning immediately, since spontaneous combustion will recur within a week if the bin is not cleaned. The bottom requires painting with asphaltic paint every two years.

Ash Removal. The ash from the traps under the economizer and air heater and from the bottom of the furnace is removed dry by scrolls operated periodically as it accumulates. The stack is sprayed as shown, ordinarily employing one 65-gpm pump on each stack for the two lower sprays, leaving one for periodic flushing of the tops. The ash is delivered through a 4-in. hard, silicon-iron pipe to the sluice that terminates in a settling basin. The pipe is provided with a lateral near the top that serves as a tell-tale overflow in case it is plugged. A temporary steel pipe was installed before the iron pipe arrived. This was worn to a thin shell in ten days and had to be patched with old inner tubes to keep it in operating condition for three weeks while the replacement was in progress.

CONSTRUCTION

The boilers are physically superimposed upon the old plant. While erection was proceeding only one of the boilers could be erected from the ground up. The ground space for the second one could not be cleared until the manufacturing peak had passed. The outside columns, however, were installed while the center columns above the first tier were supported by the wind bracing with temporary help of the old steel. In this manner the erection of the second new boiler with stack and all appurtenances above was completed until the slack manufacturing season permitted the removal of the old boilers. The bottom tier of columns was then hung in place and the foundations built below. The new boiler house possesses somewhat less volume than the old one, but the former long horizontal firing aisle is now vertical. After the new "tower" was built and half of the old boilers retained for emergency, space totaling one third of an acre and formerly occupied by the old equipment was converted into useful floor space. The ground-floor areas and volumes of the old and new boiler houses are respectively 13,000 and 6350 sq ft, and 812,000 and 659,000 cu ft.

The boilers, complete with pulverizers, economizers, air heaters, blowers, stacks, and automatic control were furnished under one contract by the Badenhausen Corporation (Riley Stoker Corp.). The remainder of the equipment and the building were assembled and erected by the company's engineering department. Since the old boilers were needed to maintain refinery operations on a 24-hr schedule, the usual ingenuity required in such cases had to be employed, with considerable week-end activity. The cost of temporary devices to maintain operation and the final removal of the old boilers was in excess of $42,000. See Table 1.

OPERATION

An ordinary day's run (August 30, 1935) requires 368 short tons of coal analyzing approximately as follows: Moisture, 2.21; volatile, 36.12; carbon, 54.91; ash, 8.91; sulphur, 2.27; heating value, 13,500 Btu; and fusing temperature of ash, 2300 F.

The steam-flow meters show the following:

Through auxiliary mechanical-drive turbines to 150-lb header, lb	3,946,800
To 2500-kw turbogenerator, lb	1,162,200
Remainder via reducing valves to 150-lb header, lb	2,728,500
Total production, 400 lb at 505 F, lb	7,837,500

BOILER

To design a boiler to fit the existing space required departure from the conventional. Nevertheless, a simple, streamline arrangement of parts was attained. The boiler can operate on natural draft from 30,000 to 80,000 lb per hr, or on forced draft from 50,000 to 250,000 lb per hr. However, the unusual requirements developed conditions not fully anticipated, which caused unusual experiences in the preliminary operation of the boilers.

Shortly after operation started, deflection of the top and bottom tubes, Nos. 18 and 1, respectively, occurred. The deflection was greatest in the tubes near the side walls. Pyrometers indicated temperatures in the No. 18 tubes of 400 to 900 F, and these fluctuated rapidly. Occasionally, a No. 18 failed at the bottom and cut a hole through the top of a No. 17 tube. On two occasions No. 1 tubes opened up at the top. This was believed to be due to starvation of water resulting from the large volume of steam produced in the waterwalls that has to pass by way of the drums through these tubes in order to reach the steam drum. The builders, therefore, installed an annular baffle in the No. 2 drum to guide the water and steam from the rear waterwall and a part of the side walls to the No. 18 tubes and thus directly to the No. 3 drum. The deflection then ceased in the No. 18 tubes. No more tubes

TABLE 1 COST OF STEAM PLANT

	Field labor			
	Hours	Cost	Material	Total
Engineering department	10,000	$ 10,362.26	....	$ 10,362.26
Clearing site and temporary work	54,525	30,501.36	$ 12,073.86	42,575.22
Building, 836 tons steel, 564 piles, 1300 yd concrete	80,909	58,785.59	98,429.37	157,214.96
Manlift	1,434	814.18	1,861.82	2,691.00
Water softener, tanks, pumps	11,658	9,631.68	64,165.73	73,797.41
Piping, valves, traps, desuperheater	15,804	8,293.61	38,933.66	47,227.27
Stack lining and washer	1,553	793.32	15,495.32	16,288.64
Coal-handling equipment	3,608	1,897.61	21,612.33	23,509.94
Ash-handling equipment	2,281	1,188.95	4,784.05	5,973.00
Fuel-oil burners and pumps (tanks not incl.)	2,134	1,111.60	6,120.21	7,231.81
Instruments and combustion control	3,221	1,657.80	16,540.90	18,198.70
Apexiorizing	2,430	1,353.86	1,453.14	2,807.00
Electric work	1,326	742.60	3,655.57	4,398.17
Insulation (about half contract)	3,249	1,564.16	11,606.12	13,170.28
Turbine adjustments, spares	385	202.58	1,836.51	2,039.09
Boilers, pulverizers, burners, fans, and turbines (contract)	51,000 (approx)	35,000.00 (approx)	485,000.00	520,000.00
Total cost of steam plant	245,517	$163,901.16	$783,583.59	$947,484.75

opened in the No. 1 row but some blisters and leaks occurred. A similar baffle was then installed in the No. 1 drum to force circulation of the water from the front waterwall and part of the side walls through these tubes. There has been no failure of these tubes since this baffle was installed about $2^1/_2$ years ago.

Lack of skill in operating technique contributed to tube failures during preliminary operation. The gas slack coal that is used slags readily, especially when mixtures arrive from several mines. When the steam-flow meter on each boiler jumps from 150,000 to 225,000 or more in from 3 to 10 min, the furnace temperature may rise too high, especially if the CO_2 meter momentarily fails to register correctly. When slagging has once started between the tubes it is difficult to stop it. Soot blowers and air lances are not always effective. Sometimes a sudden drop in the steam demand or the replacement of coal with oil for a short time has caused the slag to drop. Occasionally when slagging occurred, the operators forced the boiler through to the week end by increasing the draft. This was accompanied by tube failures due, presumably to the blow-pipe effect of the flame through the restricted passage. When slagging now occurs, which is infrequent, the boiler is immediately shut down and cleaned. The cleaning can be done in about 24 hr. Since this procedure was instituted two years ago there have been no tube failures of any kind.

Sometimes low-volatile coal with an ash of high fusion temperature is supplied. A recent shipment was delivered at $4.50 per net ton as compared with $3.80 for the gas slack. The gas slack produced steam at a fuel cost of $0.17 per 1000 lb. To arrive at the same cost with the low-volatile coal would require a price reduction to $4.10, but this coal left the boiler perfectly clean and increased the comfort to the operators. The fear complex which induces the operators to maintain a CO_2 content low enough to prevent slagging with the high-volatile coal prevents them from getting the most out of a short run of coal that can stand a higher temperature. The cost of cleaning, some increase in maintenance (especially in the pulverizers), together with extra operating vigilance that the cheap coal requires do not compensate for the increased cost of the low-volatile coal. Treatment of coal with "chloride" and with molybdenum sulphide for reducing the slagging tendency has indicated some improvement, but a long period of trial will be necessary before a conclusion can be reached.

The superheater tubes, originally installed vertically between the boiler tubes, are now in a horizontal position above the boiler tubes. This made the boiler tubes more accessible for cleaning and is thought to have decreased the slagging tendency. This change did not affect the superheat. At the same time the superheater-tube outlets were changed from the original position at the end of the horizontal diameter to the top. This made a better separator and was especially advantageous before the water-softening operation was improved. One of the old superheater tubes failed at the bend of the "hair-pin." This tube was, of course, scoured clean. The next tube was cut out for inspection and was found to be full of scale. All of the tubes were then cleaned by see-sawing a chain through them. No repetition of this cleaning has been required.

FEED PUMPS

When the total steam produced exceeds 380,000 lb per hr, two feed pumps are used. For any amount from 50,000 (on Sundays) to 380,000 lb, one pump with its excess-pressure governor serves satisfactorily. During preliminary operation when the demand dropped to 30,000 lb, the rotor seized. Evidently not enough water was going through the pump to prevent steam binding. The balancing loop from the discharge to the suction is now connected with a small pipe to the feed tank.

PULVERIZERS AND BURNERS

The purchasing agent had been fretting under the restrictions placed upon him by the old furnaces. During the last year of operation of the old plant 103,000 tons of low-volatile coal at $4.41 per net ton was consumed. The following year the new boilers with a 10 per cent increase in performance, burned 85,000 tons at $3.20 per ton. One cargo was purchased at 10 cents per ton f.o.b. mine. Then came a cargo of Pocahontas. Then a few carloads of river anthracite. The anthracite contained 10 per cent of moisture and refused to flow out of the bunkers without pokers. However, with an auxiliary oil burner it was able to make steam. The most discomforting feature of the promiscuous mixing of coals was the slagging tendency. The average cost of repair parts for the pulverizers and burners during the first four years of operation is 6 cents per net ton of coal burned.

TURBINES

The auxiliaries are driven by 15 mechanical-drive turbines taking steam at 400 lb and exhausting at 150 lb. These are provided with labyrinth glands which are satisfactory in this plant as the leak-off is used in the process for heating water. During preliminary operation some blades were lost and the cause is suspected to have been water carry over. When this occurred, vibration damaged the labyrinth gland, which had to be renewed. At the beginning of the operation there have been times when an almost instantaneous load of 180,000 lb per hr was thrown onto or off the boilers. The operators now cushion this load by the aid of the accumulator. Previously, the water-level recorder showed a spear of 14 in. that did not last more than five minutes but long enough to cause damage to an occasional turbine blade. On one occasion a repair man accidentally shut off the oil pump that furnishes pressure oil for operating the reducing valve that reduces the surplus 400-lb steam to 150 lb. Immediately the steaming rate of each of the boilers, which happened to be at 150,000 lb, dropped to 75,000 lb, and a few minutes later, when the operator opened the reducing valve manually, the rate jumped to 240,000 lb per hr. The water-level recorder recorded a vertical line 16 in. higher than the average. Two weeks later one of the turbines vibrated and it was found that a short piece of shroud had been torn off.

The disk of a butterfly control valve in front of one of the turbines was fastened by means of a setscrew. One day vigorous vibration in the turbine required it to be shut down. The setscrew had come out and done damage to the extent of $800. Thereafter, setscrews located in such precarious positions were spot-welded.

On another occasion a wheel became unbalanced and vibrated vigorously. It was suspected that a setscrew balancing plug had come out, but the evidence could not be located. One of the pulverizer drive wheels and shaft became pitted. This was believed to be due to steam leaking through the throttle during idle periods. Following this, each turbine was provided with a second valve at both throttle and exhaust, with a leak-off between. In case repairs are now needed, the work can be done in comfort.

DRAFT FANS

After two years of operation the rim of the involute of the induced-draft fan became considerably eroded. This was then covered with a serrated cast-iron liner which promises indefinite protection.

DESUPERHEATER

The desuperheater offered resistance to the steam flow and was accordingly by-passed. The superheat in the 30-lb reduced-pressure steam is 100 F as it enters the 4000-sq ft pans. A spray of condensate was pumped into the steamline feeding these pans and the thermometer showed that this reduced the superheat to zero. However, the steam-flow meter showed no effect on the rate of evaporation in the pans. The superheat made no discernible difference. The desuperheater was therefore removed. Since superheated steam has been in use the accumulator water content must occasionally be replenished while previously it had to be drained.

FEEDWATER CONTROL

The feedwater is controlled by a double-control regulator as shown in Fig. 3. It consists of a water-level thermostat and a steam-flow thermostat connected by adjustable levers to the control valve. The water-level thermostat is actuated by changes in the boiler-water level. The steam-flow thermostat is actuated by the pressure loss across an orifice in the main steam header.

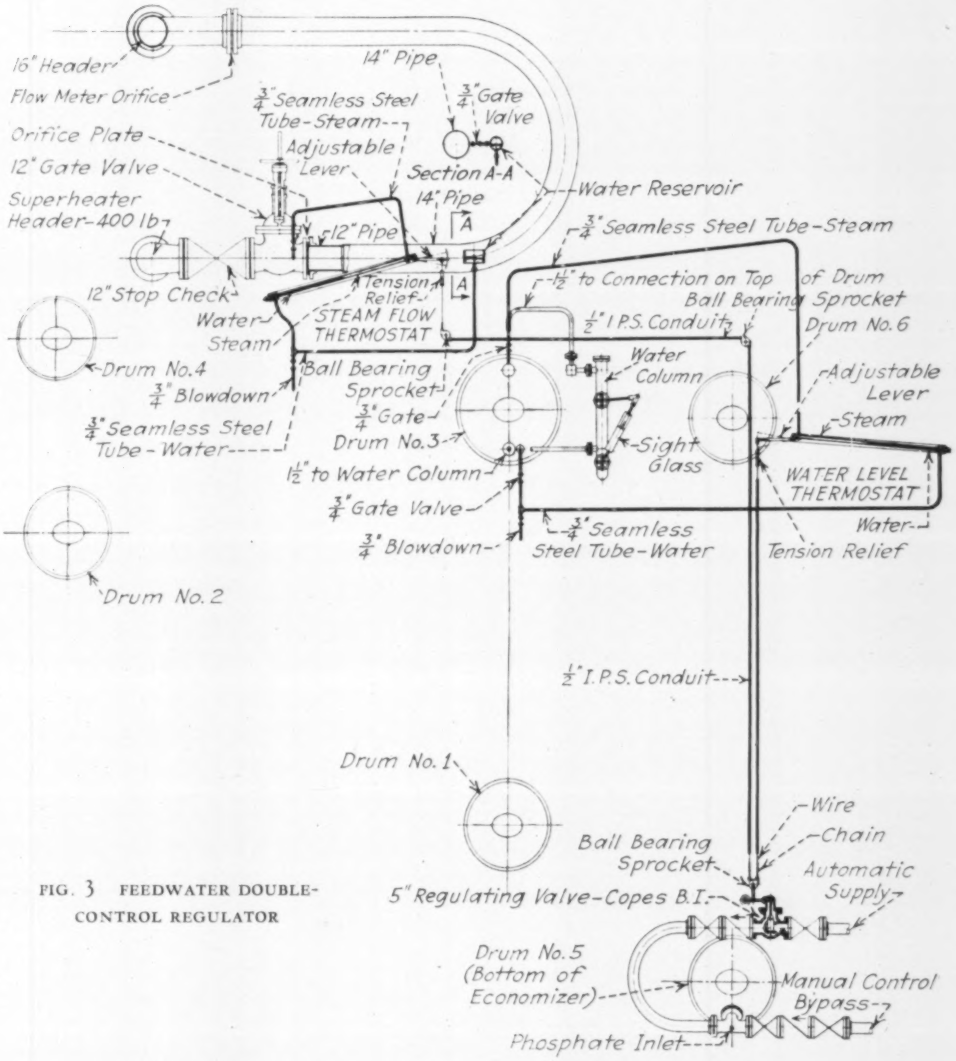
16" Header
Flow Meter Orifice
14" Pipe
3/4" Seamless Steel Tube-Steam
3/4" Gate Valve
Orifice Plate
Adjustable Lever
12" Gate Valve
Section A-A
Water Reservoir
14" Pipe
Superheater Header-400 lb
A
12" Pipe
3/4" Seamless Steel Tube-Steam
1 1/2" to Connection on Top of Drum
12" Stop Check
Tension Relief
A
Ball Bearing Sprocket
Water
Steam
STEAM FLOW THERMOSTAT
1/2" I.P.S. Conduit
Drum No. 6
Water Column
Drum No. 4
Ball Bearing Sprocket
Adjustable Lever
3/4" Blowdown
3/4" Gate
Steam
3/4" Seamless Steel Tube - Water
Drum No. 3
Sight Glass
1 1/2" to Water Column
WATER LEVEL THERMOSTAT
3/4" Gate Valve
3/4" Seamless Steel Tube - Water
Water
3/4" Blowdown
Tension Relief
Drum No. 2
1/2" I.P.S. Conduit
Drum No. 1
Wire
Chain
Ball Bearing Sprocket
Automatic Supply
5" Regulating Valve-Copes B.I.
Drum No. 5 (Bottom of Economizer)
Manual Control Bypass
Phosphate Inlet

FIG. 3 FEEDWATER DOUBLE-CONTROL REGULATOR

With no load on the boiler, the steam-flow thermostat is full of water provided by a condensate reservoir. As the steam flow from the boiler increases, the drop across the orifice pushes the water down in the expansion tube of the steam-flow thermostat. This exposes a greater portion of the tube to hot steam, causing the tube to expand and move the levers in the direction to open the feed-control valve. The increased steam flow is accompanied by swelling of the water in the drum because of lowering pressure that permits the number and size of steam bubbles circulating with the water in the tubes to increase. This increased water level reacts on the water-level thermostat causing it to contract and move the levers in a direction to throttle the feed-control valve.

The water-level thermostat alone will throttle the feed valve momentarily when increased steam production causes the boiler water to swell. With a decrease in steam production, there is a corresponding contraction of the boiler water and the water-level thermostat alone tends to open the valve. This would result in an uncomfortably high water level in case of a sudden large drop in steam flow. The steam-flow thermostat opens the feed valve when steam flow increases and closes it when steam flow decreases. This action tends to counteract the effect of swell and contraction in the drum. Since the relative influence of the two thermostats is adjustable, proper leverage for each thermostat is determined to maintain a reasonably constant boiler-water level.

When the water-level thermostat was used alone, the level jumped six inches with steam demand increases of 100,000 lb in 10 min. It has happened that when the operators did not correctly anticipate the demands in process, a sudden pull (with the accumulator low) has raised the water level 10 in. The double-control regulator now maintains the water level within plus or minus two inches under the most unruly conditions.

An excess-pressure governor is part of the feed-control system. It maintains an unvarying excess pressure in the feed line with variations in quantity between 30,000 and 380,000 lb per hr. This is accomplished by controlling the steam to the turbine driving the boiler-feed pump.

ACCUMULATOR

The accumulator is 16 ft in diameter and 60 ft long and weighs 700 tons when loaded. On account of the lack of ground space it was erected on the roof of the pan house, 129 ft above the ground. The maximum pressure is 150 lb, and, since it makes up to the exhaust-steam system at 10 lb and to the supply to vacuum pans at 30, its minimum pressure is about 50 lb. The storage capacity between these limits is 42,000 lb of steam. When there is a sudden drop in the demand for steam, the accumulator fills. When 2, 3, or 4 pans are started simultaneously, or nearly so, each drawing at the rate of 70,000 lb per hr, a supply of steam is immediately

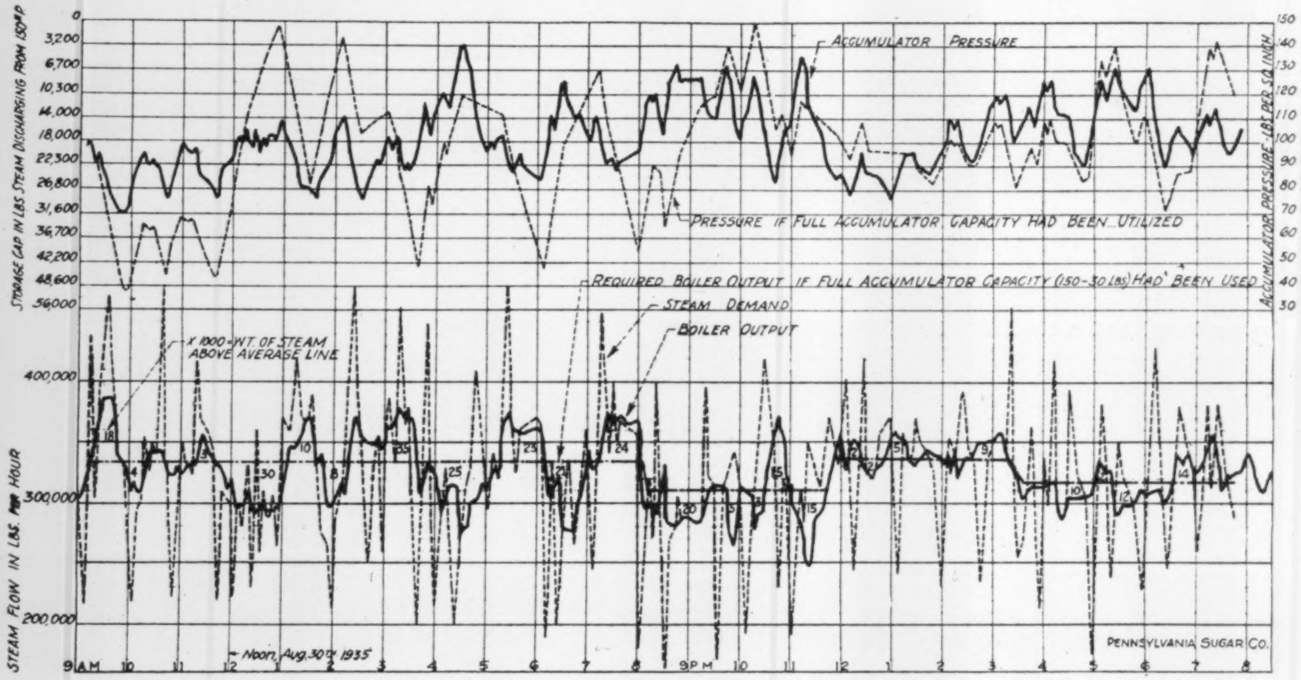

FIG. 4 STEAM DEMAND AND STEAM PRODUCTION, PENNSYLVANIA SUGAR COMPANY

available without passing the jolt onto the boilers. Fig. 4 shows the steam demand compared with steam production. If the boiler operators could anticipate the demand, the production graph could be made nearly straight. An instrument is now being built which will draw heavy lines on a time strip to show when the heavy steam consumers went into service. Since the cycles of these machines are known, the operators will be able to anticipate the time when the machines will be turned off or on.

The original purpose of the accumulator was to secure the flywheel effect in leveling the production peaks, and thereby improve the efficiency of the boilers. It has since justified itself in other and unexpected ways. In combination with a modern high-pressure boiler it has the advantages, without the limitations, of the long rows of Scotch marine boilers formerly used in some of the old Michigan beet-sugar plants.

When the first tube failure occurred, the operators did not immediately sense the situation and did not speed up the second boiler. In the meantime the plant continued to draw heavily on the 150-lb exhaust from the auxiliary-drive turbines. This reduced the pressure and caused overspeeding, tripped all of the governors, and therefore shut down the feed pumps, pulverizers, and blowers of both boilers. The generator engines (150 lb) then slowed down so as to trip the breakers that controlled the fuel-oil motors and the oil pump for the control of the reducing and accumulator valves. In this predicament, the operator shut off the accumulator against the process header and opened the overflow valve so as to allow the accumulator to feed the generator engines. Presently, the lights brightened, and within seven minutes the idle boiler was back in service while the old emergency boilers were groomed to replace the one that failed. If the reserve of the accumulator had not been available, the plant would have been in darkness until enough scrap wood could have been found to get up steam.

During the week end one boiler is taken off. The auxiliary turbines produce 150-lb exhaust that drives two 500-kw Corliss-engine generators. Sometimes there is a little too much steam, but more often a slight deficiency. Under this condition there is hunting of the make-up reducing valve or blowing of the safety valve. The overflow valve to the accumulator is now kept open on week ends and the reducing valve adjusted to about 145 lb. The accumulator then takes care of the fluctuations and keeps the steam flowing comfortably.

At the week end only one pulverizer is required. On Sunday nights when the steam demand increases, a draft is made on the accumulator until two pulverizers can be put on. By the time the accumulator has been refilled, the demand has caught up with the capacity of two pulverizers. As demand increases, the accumulator is drawn down again until the third pulverizer or the second boiler is required.

Sometimes on a week end it is desired to pack valves or make repairs on the 400-lb lines that cannot be made under pressure. Or, if the by-products plant is shut down and the steam demand drops to 30,000 lb per hr (i.e., about one twelfth the normal demand) it is advantageous to drop the pressure to 150 lb. This permits operating with fuel oil and natural draft and shutting down the turbine-driven auxiliaries. Both in reducing the 400-lb pressure and in returning there is a period when no feedwater can be supplied since the turbine-driven pump (there being no electric-driven auxiliary) does not operate when the pressure is below 300 lb and the old feed pump cannot exceed 200 lb. In this case the accumulator supplies the steam for about 15 min while the pressure changes.

About once a year it is necessary to "kill" the switchboard to permit the electricians to make repairs or extensions. For such occasions the accumulator is filled and closed and the steam and power plants shut down. After a half-day's work on the switchboard, the accumulator supplies steam for the engines and promptly provides the power to return the boilers to service.

CONTROL

The automatic control is mechanically operated. It controls the furnace draft, speed of induced- and forced-draft fans, the

TABLE 2 STATISTICS OF FEEDWATER TREATMENT

	1933 Lime soda ash	1934 Lime soda ash	1935 Primary
Raw water, lb	1,100,579,000	932,277,300	851,295,500
Alkalinity, ppm $CaCO_3$	......	34.4	32.1
Total hardness, ppm $CaCO_3$	......	48.7	38.3
Filtered water			
Alkalinity to Pht, ppm $CaCO_3$	......	24.9	7.9
Alkalinity to MO, ppm $CaCO_3$	......	50.5	42.4
Hardness, ppm $CaCO_3$	......	27.3	4.5
Condensate return water, lb	779,670,100	988,414,300	1,012,713,300
Per cent of total feedwater	41.4	51.46	54.32
Feedwater, total, lb	1,880,249,100	1,920,691,600	1,864,008,800
Steam, new and old boilers, lb	1,833,570,100	1,841,734,100	1,788,410,000
Blow-down water, lb	46,679,000	78,957,500	75,598,800
Per cent of feedwater	2.48	4.32	4.25
Alkalinity to Pht, gr per gal $CaCO_3$	......	17.5	15.1
Alkalinity to MO, gr per gal $CaCO_3$	......	29.5	23.1
Alkalinity to OH, gr per gal $CaCO_3$	......	13.5	12.0
Phosphate, gr per gal Na_3PO_4	......	13.9	8.8
Sulphate, ppm SO_4	......	802	672
Sulphate-carbonate ratio	......	3.8	3.5
Chemical cost	$4,517.68	$4,857.83	$4,340.35
Per million lb raw	4.104	5.210	5.098
Per million lb boiler feed	2.402	2.529	2.328
Per million lb steam	2.463	2.637	2.427

TABLE 3 COST OF PRODUCING STEAM, 1935

	Material	Labor	Total	Dollars per 1000 lb steam
Repairs and Maintenance				
Buildings	$ 589.59	$ 762.55		
Boilers	7,170.45	5,835.47		
Water supply	1,930.24	2,453.85		
Fuel supply	14,087.63	4,694.56		
Ash removal	1,373.23	288.96		
Instruments, piping	1,077.76	1,254.04		
Total repair and maintenance	$26,228.90	$15,289.43	$ 41,518.33	0.0232
Operation				
Boilers	......	25,122.90	......	....
Softener	4.818.92	5,046.60	......	....
Cleaning and apexiorizing	1,253.59	2,231.63	......	....
Fuel and ash (mtl = frt. on ash)	1,540.00	6,674.79	......	....
Lubricating oil, instruments, misc	2,785.77	808.72	......	....
Total operation	......	......	$ 50,278.92	0.0282
Power for auxiliaries (approx.)	......	......	$ 10,229.13	0.0057
Fuel, coal, 84,054 net tons	348,606.47	......	......	....
Fuel, oil, 9,804 bbl	10,801.20	......	......	....
Total fuel	......	......	$359,407.67	0.2009
Depreciation, insurance, and taxes	......	......	$ 48,676.42	0.0272
Total cost per 1000 lb steam, dollars	......	......	......	0.2852

secondary air to the burners, and the rate of coal fed to the pulverizers. Since the boiler pressure provides the impulse under which this apparatus operates, it tends to maintain a constant pressure. The automatic control responds too speedily to the demand without giving the accumulator an opportunity to function. It is therefore usually switched off in favor of hand control. The manipulation proceeds according to the condition of the accumulator so as to accelerate or decelerate the action to allow comfortable modulations in the load in the storage vessel. A device has been designed to accomplish the variation in the speed of the control mechanism automatically but it is thought best for the present not to relax the operator's vigilance. When a time-cycle indicator has been installed by means of which demand can be anticipated the control will be simple. The operators in this plant prefer the mechanical control under the argument that it is independent of electric-power interruptions—but this has occurred only once and then only for a few seconds when a tube blew up.

FEEDWATER TREATMENT

About 50 per cent of the feedwater is condensate; the remainder which passes through the softener is Delaware River water which has passed through jet condensers from evaporators and vacuum pans where it becomes heated to about 125 F and occasionally picks up some sugar through accidental carry over. The surfaces of heaters, evaporators, and vacuum pans in the refinery total 56,000 sq ft. These surfaces sometimes develop leaks and thereby contaminate the condensate. This contamination reduces the alkalinity of the boiler feed. To combat accidents, two boiler-feed tanks having a capacity of 432,000 lb each are provided to serve alternate weeks. The tank that is not in use is kept full of softened water at a temperature of 240 F to be immediately available in case the operating tank becomes contaminated. In case sugar reaches the boiler, caustic soda is pumped into the feedwater line by means of the pumps formerly used for phosphate. Accidents of this kind are infrequent as the presence of sugar is detected by Leeds and Northrup conductivity meters with electrodes installed respectively in the two sources of feedwater. In the case of the condensate, the meter shuts down the pump which delivers the water to the softener station as soon as sugar is detected in the water.

The record of the Delaware River water tests of the past two years shows a variation in the total hardness of 30 to 60 ppm as calcium carbonate and in the bicarbonate hardness of 20 to 50 ppm as calcium carbonate. This water was originally treated by the conventional hot-process softener using lime and soda ash and was thus reduced to a minimum hardness of 17 ppm. This water, together with an equal amount of condensate, passed through the deaerating heater to the feed tank and thence to the boilers. To reduce the hardness to zero, phosphate was pumped into the boilers entering by way of the feedwater inlet at the lower drum of the economizer. This resulted in a calcium-phosphate precipitate that adhered as a sludge to the tube surfaces, especially in the economizers, and aggravated carry over that fouled the superheaters, valves, and turbines. To avoid this precipitate, primary treatment was instituted in January, 1935, using phosphate and caustic soda in the sedimentation tank instead of lime and soda ash. The only plant change required was the replacement of calcium-carbonate sand with graded magnetite in the sand filters. The former phosphate pumps are now used only for emergency pumping of caustic soda in case of accidental sugar contamination in the feedwater; the stirrer in the chemical tank is idle.

With the removal of the sludge, the carry over disappeared. A little deposit still accumulates in the economizer, which requires brushing at four- or five-month intervals. Previously a heavy layer had to be brushed out every three months. At the end of the year there was a small amount of scale in some of the tubes. By way of precaution in respect to tubes that could not be inspected throughout their whole length the entire boiler, including the waterwall, was turbined and apexiorized. With better control of condensate pollution it may be possible to dispense with this work. The hardness is practically zero with a maximum of 5 ppm. A more uniform quality of water is now maintained in the boilers. By the former method it was found impracticable to feed phosphate continuously, exactly proportioned to the need. The intermittent feeding caused fluctuations in the concentrations and required frequent tests. A high concentration caused a reduction in the alkalinity, a condition which is also symtomatic of sugar pollution. The control is greatly simplified. Statistics of treatment are to be found in Table 2.

COST OF STEAM PRODUCTION

In 1935 the steam produced in the old boilers, at 150 lb and 5 per cent moisture, amounted to 84,931,300 lb, and in the new boilers at 400 lb and 505 F, it amounted to 1,703,418,700 lb, a total in both of 1,788,350,000 lb. The costs of producing this steam are listed in Table 3.

Under repair and maintenance the old boilers and building account for one quarter of the expense. The old boilers replace one of the two new ones for emergency and at the year-end inspection period. Two of the old boilers burn oil, while the rest require a low-volatile coal that costs about a dollar more per ton than that used by the new boilers. The fuel consumed by the new boilers was 82,000 tons of coal plus 3500 barrels of bunker "C" fuel oil.

Estimating the heating value of the coal as fired at 13,550 Btu, the overall annual efficiency is 80 per cent. One boiler was down every week end from one to three days during which time the other one produced from 50,000 to 80,000 lb of steam per hr.

SUPERPOSITION

(*Continued from p. 572*)

water, and particularly so in the case of constant-speed pumps.

LIMITATIONS

A note of caution may well be given to the effect that there is a limit to the amount of superposed capacity that may be installed in any system. This amount is a function of the lowest hourly loads that may occur. It is easily possible that the lowest load may be 40 per cent of full load, and even 25 per cent in cases where some hydro capacity exists. The superposed station is really a large cross-compounded unit, and as such may form a large proportion of the total load. On a large system it may be undesirable to shut down completely some plants in order not to lose local protection, to maintain system stability, or for other good reasons. This may mean that the superposed plant may have to operate at 20 per cent of capacity, and care must be exercised in the design that this may be accomplished. In particular the boiler must be able so to function. If a slagging bottom is selected for the furnace, difficulties may arise in reducing the load on the superposed plant for the best system efficiency; the limit being low load. On the other hand, a dry-bottom furnace may place a limit on the maximum output because high furnace temperatures may cause the ash to fuse in the bottom, making removal difficult. It is wise to make fusion analyses of all the types of coal and their combinations that are likely to be used.

Some plants may have to meet such low-load conditions that the no-load flow through the superposed turbine may give excess capacity on the low-pressure units. This is not likely to happen at Logan, where the no-load flow is about 225,000 lb per hr, which would only carry about 15,000 kw of low-pressure capacity, or 16 per cent of the rated plant capacity. For plants that must at times operate at less than 20 per cent capacity, superposition might prove embarrassing.

CONCLUSION

Advantages of superposition may be summarized as follows:

1 No increase in coal-handling facilities is needed, for although the capacity may be increased by about 80 per cent, the coal required per kilowatthour is decreased by about the same amount.

2 No increase in condensing equipment is required unless the pressure on the old turbines is decreased too much, say from 300 to perhaps 200 lb per sq in.

3 Capacity requiring only some 4000 Btu per kwhr is added at no more cost than for the same condensing capacity.

4 It brings old plants relegated to peak-load service back to an economical basis, with almost as good efficiency as the most modern condensing designs available. It is possible to reduce the coal consumption of a plant in some cases from 2 to 1 lb per kwhr.

5 It is more adaptable to plants having existing turbines built for pressures of 350 lb or lower and temperatures of 600 F and lower.

6 Where condensing-water supply is limited, as at Logan, capacity may be installed that would otherwise be impossible except for superposition.

7 Where subsoil conditions necessitate expensive foundations, the superposed turbines require lighter and less expensive foundations.

8 Some older stations have turbine capacity in excess of boiler capacity. Thus additional low-pressure turbine capacity, which formerly could not be used, is made available by superposition.

9 Frequently, no additions need be made to existing building, cranes, condensing-water system, and certain electrical equipment, and such auxiliaries as air compressors, service-water pumps, and water-treatment plants.

10 In many cases the size of the superposed units will fit load growth more closely than would the best-sized condensing unit.

This paper does not pretend to cover all possible plans and phases of superposition but briefly to summarize a few of the salient elements that have been encountered. After all, a superposition design embraces all the problems of thermodynamics, metallurgy, plant layout, and equipment that must be solved in the design of standard power plants. This subject is so broad that every day brings some new development or idea, tending to make a design obsolete before the drawings become an actuality. The temptation to discuss plant design is strong, but such discussion will doubtless be of greater value after the designs have been completed and some operating experience has been gained with the present superposed plants now under way. This paper will have served its purpose is some attention has been directed to the valuable possibilities of rehabilitating obsolete plants by superposition and if the discussion thereof stimulates new ideas of value to producers of electrical power.

A SUPERPOSED POWER STATION

Improvements in Plant Facilities at Cincinnati West End Station for High-Temperature, High-Pressure Operation

By D. S. BROWN

THE UNION GAS AND ELECTRIC COMPANY, CINCINNATI, OHIO

IN 1916, the peak load of the Cincinnati system was 36,000 kw, and was supplied by the Plum Street Station. Due to the World War, the expansion of industrial activity in Cincinnati at this time caused a rapid increase in the demand for electric power and in 1916 the construction of West End power station was begun.

The first section of this station consisted of the present building and two 25,000-kw turbogenerators, supplied by eight boilers evaporating steam at 260 lb per sq in. and 600 F. These two units were put in service in the summer of 1918 and were followed in 1920 and 1921 by two additional units which brought the capacity of the station to 100,000 kw in four turbines supplied by 14 boilers.

In 1928 and 1929, these four turbines were rebuilt, new diaphragms were installed in the first 11 stages, a thirteenth stage extraction heater was provided, and new generators of 45,000 kva each were added. The rating of the rebuilt turbines was thus increased to 36,000 kw each, and the rating of the station was increased to 144,000 kw.

During the next three years, a more or less continuous recession in the system load decreased it from 187,000 kw in the fall of 1929 to 148,000 kw in the summer of 1932—a decrease of approximately 20 per cent. Since 1932, the load has increased in uncertain and unpredictable steps until, at the end of 1935, the Cincinnati peak was 206,000 kw, or 10 per cent above the peak of 1929.

This increasing load required that engineering studies be made of new generating capacity, and toward the end of 1935 a decision was made to proceed with a 35,000-kw superposed unit for the West End station. The steam for this new unit will be generated in three boilers and supplied to the turbine at a pressure of 1200 lb per sq in. and a temperature of 900 F. Steam for this unit will be exhausted at a pressure of 260 lb per sq in. into existing turbine headers and will then pass through the present machines to the condensers.

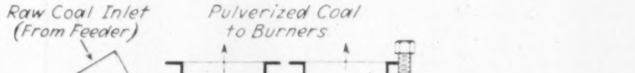

FIG. 1 COAL-PULVERIZING MILL

(Cross section through a 232 B. and W. pulverizer, having a capacity of ten tons of coal per hour. This is an air-separation mill and two mills are used for firing each boiler directly.)

DESIGN

In designing and in laying out this new equipment, a prime consideration is to make use, in so far as is economically possible, of existing building structure and equipment. As an illustration the width of the boilers is such that they fit between existing building columns just as well as the original boilers did.

In order to make room for the three new boilers and the new turbine, four old boilers are being removed from the southwest corner of the boiler room. The new turbine will be located as close to the present turbine room as possible and on the same floor level and parallel to the present turbines.

The present wall between the turbine room and boiler room will be removed so that the operation of the new turbine can be readily combined with the operation of the two present units.

Cottrell precipitators or dust collectors will be located on the building steel which formerly supported the economizers.

The ash-handling system has been laid out so as to make use of one of the old coal cranes, which will be displaced by the new coal-handling equipment.

COAL HANDLING

The present coal-handling equipment is of the open type. Coal is brought into the station in side-dump cars and emptied into pits from which it is handled by overhead cranes with clam-shell buckets and dropped into the open bunkers above the stokers. While this system is quite reliable and is operated at low cost, it is extremely dirty and coal dust travels to all parts of the plant. This system is also affected by high water and it would be quite a problem to operate it with the river stage above 65 ft.

Presented at a meeting of the Cincinnati Section, Cincinnati, Ohio, May 28, 1936, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

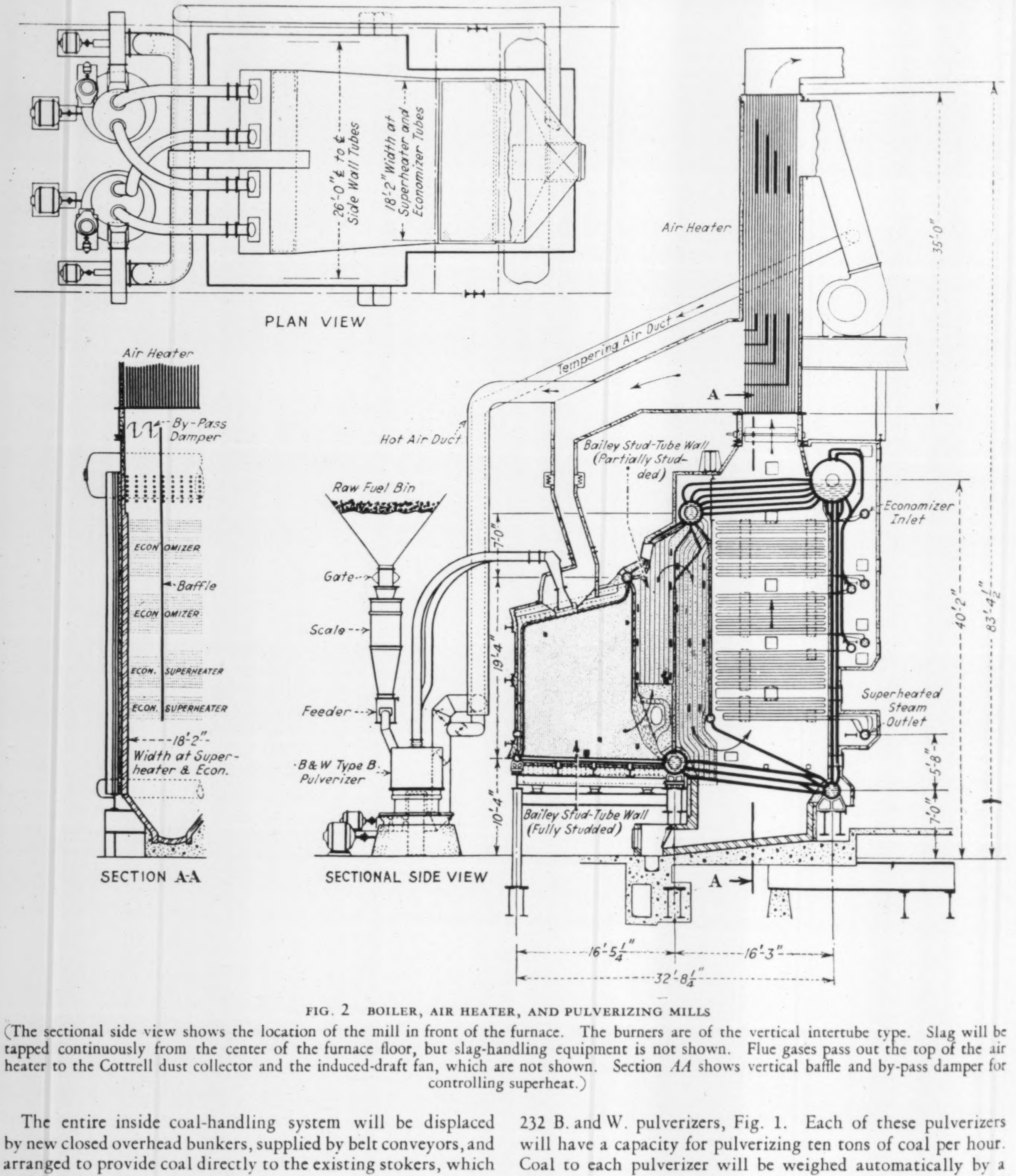
26'-0" ℄ to ℄ Side Wall Tubes
18'-2" Width at Superheater and Economizer Tubes
PLAN VIEW
Air Heater
By-Pass Damper
ECON OMIZER
Baffle
ECON OMIZER
ECON. SUPERHEATER
ECON. SUPERHEATER
18'-2" Width at Superheater & Econ.
SECTION A-A
Air Heater
35'-0"
Tempering Air Duct
A
Hot Air Duct
Bailey Stud-Tube Wall (Partially Studded)
Raw Fuel Bin
Gate
Scale
Feeder
B&W Type B. Pulverizer
Economizer Inlet
Superheated Steam Outlet
7'-0"
19'-4"
10'-4"
40'-2"
83'-4½"
5'-8"
7'-0"
Bailey Stud-Tube Wall (Fully Studded)
SECTIONAL SIDE VIEW
16'-5¼"
16'-3"
32'-8¼"

FIG. 2 BOILER, AIR HEATER, AND PULVERIZING MILLS

(The sectional side view shows the location of the mill in front of the furnace. The burners are of the vertical intertube type. Slag will be tapped continuously from the center of the furnace floor, but slag-handling equipment is not shown. Flue gases pass out the top of the air heater to the Cottrell dust collector and the induced-draft fan, which are not shown. Section *AA* shows vertical baffle and by-pass damper for controlling superheat.)

The entire inside coal-handling system will be displaced by new closed overhead bunkers, supplied by belt conveyors, and arranged to provide coal directly to the existing stokers, which will be left in the station, and also to the new pulverizing mills. The coal-conveyor equipment outside the station will be independent of high water. Every effort will be made to minimize coal dust and confine it to the coal-handling system so that it will not be spread through the plant.

PULVERIZED-FUEL EQUIPMENT

Each boiler will be fired directly with pulverized coal by two 232 B. and W. pulverizers, Fig. 1. Each of these pulverizers will have a capacity for pulverizing ten tons of coal per hour. Coal to each pulverizer will be weighed automatically by a Richardson scale located in the coal duct between the coal bunkers and the mill. The supply of coal to each mill will be regulated by a Bailey feeder.

The pulverizing mill consists of a double row of balls driven from a vertical shaft by a constant-speed motor. Primary air drawn from the air heater is blown through the mill and carries the finely pulverized coal to the furnace, as seen in Fig. 2. This air is supplied by a motor-driven fan, and, in addition to carrying the coal from the mill, supplies sufficient heat to dry the coal in the mill.

The primary air and the coal which it carries in suspension are admitted to the furnace through a burner which divides the coal and air into a number of narrow streams and discharges them into the furnace between the water tubes which form the roof of the furnace.

Secondary air is admitted at the burner through an inlet box which entirely surrounds the burner proper. Thus all coal and air which are necessary for combustion are supplied at the burner.

Each mill supplies two burners, and there will be four burners installed across the front of each boiler.

BOILERS

Three steam-generating units, Fig. 2, are being installed with the turbine. Since the steam supplied to the high-pressure turbine will, in turn, be passed on at reduced pressure to two low-pressure turbines, it was considered desirable to take the steam from three units—no one of which was larger than the capacity of a turbine—in order to insure maximum availability of steam supply. This determined the maximum capacity of a boiler to be 350,000 lb per hr, and the high-duty, integral-type boiler selected for this job is a low and compact unit which is being installed in the existing building with minimum changes to the building steel.

The steam drums on these units are designed for a working steam pressure of 1450 lb per sq in., and the superheaters are designed for a maximum total temperature of 925 F.

Burners will be arranged for vertical firing, and a new design of slag-tap furnace, which is capable of handling coals with ash fusion temperatures varying from 2400 to 2800 F, will be used.

The walls and floor of the furnaces will be of full-stud tubes covered with chrome ore. The slag opening will be near the center of the floor and arranged for continuous tapping of the slag.

Between the furnace and the superheater are two vertical open passes of partial stud-tube construction which present a high heat-absorbing surface for rapidly cooling the gases and eliminating the necessity for a bank of tubes which may become slagged.

Ash which collects in the first pass will drop to the bottom and melt on the furnace floor. Ash from the second pass will fall into an ash hopper at the bottom of the superheater. This arrangement of vertical passes eliminates all possibility of direct radiation from the furnace to the superheater. This should prevent any slag from sticking to the superheater and result in easily cleaned convection surfaces throughout the unit.

The superheater extends about 80 per cent of the distance across the unit. The remaining 20 per cent is a section of the economizer equipped with a vertical baffle so that the gases can be completely shut off from this economizer section. This will permit a reasonable amount of superheat control at all loads and is of particular value in controlling the temperature at the exhaust of the high-pressure turbine.

These slag-tap furnaces have a high combustion efficiency

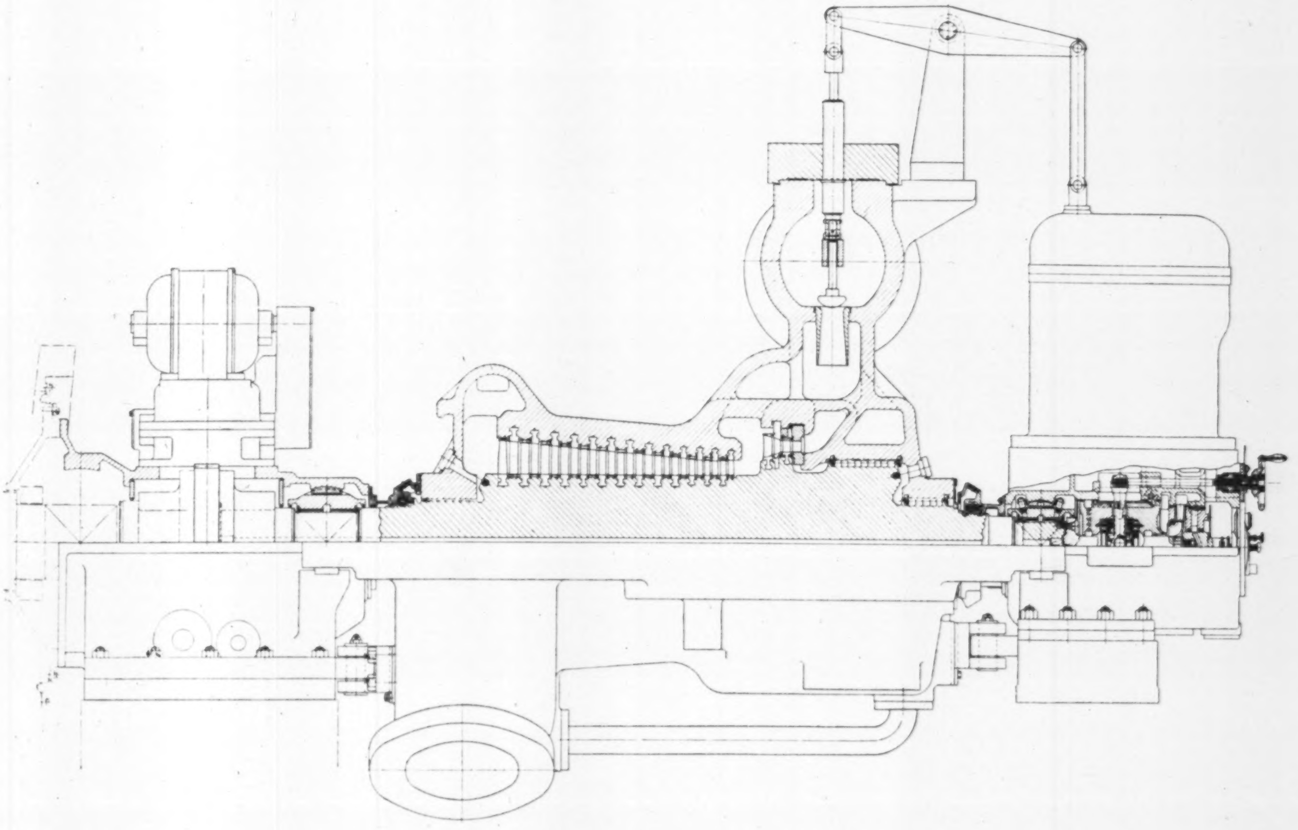

FIG. 3 35,000-KW TURBINE

(Cross section through the main turbine unit. The operating governor is enclosed in the dome on the right and linked to the control valves in the steam chest, which is in the top of the upper cylinder casing. The Curtis element and reaction stages are clearly shown. The turning gear is mounted over the main coupling.)

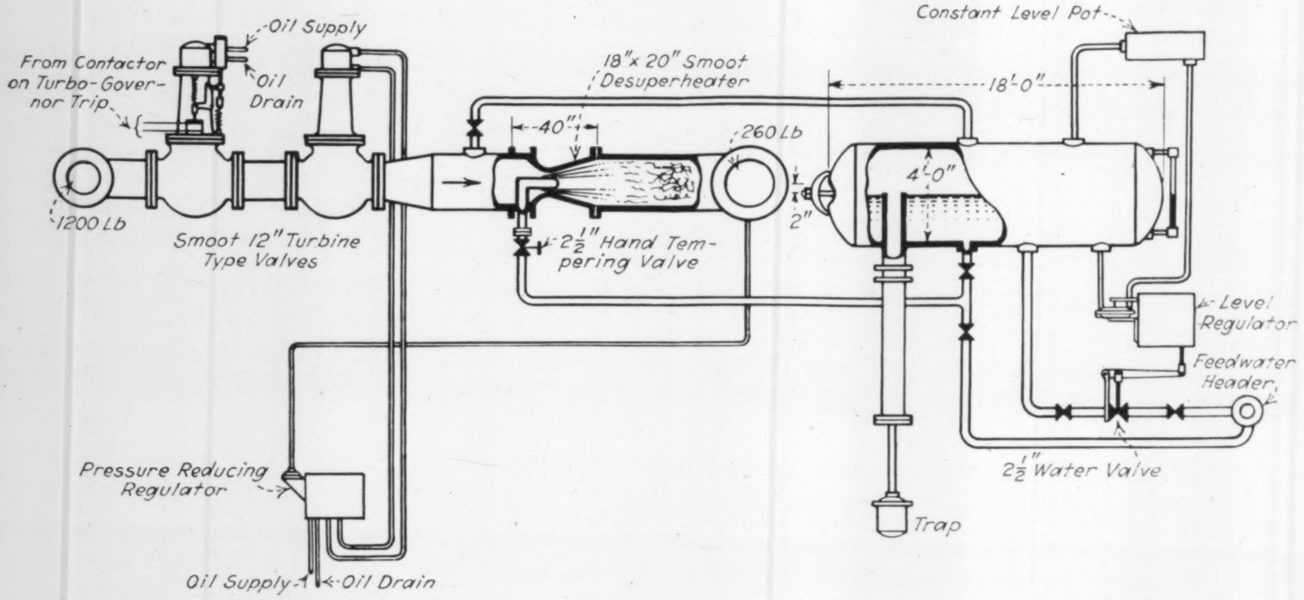

FIG. 4 FEEDWATER CYCLE

(Showing arrangement of the new high-pressure boilers and turbine, the pressure reducer and desuperheater, the new feedwater heaters, evaporator, and high-pressure boiler-feed pumps, and how they will be tied into the present lower-pressure equipment.)

and allow for the greatest recovery of ash in the furnace, which should result in cleaner convection surfaces. The vertical firing provides rapid and complete combustion with high heat releases and maintains the slag at a high temperature, which results in easier tapping. Since the ash fusion temperature is as high as 2800 F, this is very desirable.

At 350,000 lb of steam per hour, the heat liberation in the complete furnace, including the open passes, is 56,000 Btu per cu ft.

ASH HANDLING

Ash which collects in the furnace or drops back into the furnace from the first vertical pass will be fused to a liquid on the furnace floor. It will then drip continuously through an opening near the center of the floor into a tank of still water located in the basement underneath the furnace. The quenched slag will collect in this tank and will be flushed intermittently into a sluice. Dry ash that may collect in the large hopper underneath the superheater will be discharged intermittently into this same sluice.

The fine dust or fly-ash which passes through the boiler and air heater will be collected by an electrostatic precipitator located above the boilers. This fine material will be collected in hoppers and discharged intermittently into the sluice.

The sluice will carry the slag, ash, and dust into a pit which is at the east end of the boiler room, where it will be removed by a clam-shell bucket and then loaded into railroad cars for disposal.

TURBINE

The new high-pressure turbine, Fig. 3, is rated at 35,000 kw, with a maximum rating of 40,000 kw when supplied with steam at a pressure of 1200 lb per sq in. gage and total temperature of 900 F, and operating with a back pressure of 260 lb per sq in. gage. The exhaust steam from this unit will be supplied to the present low-pressure turbines, and the size of the high-pressure unit has been selected in order to supply two low-pressure units, see Fig. 4.

Steam is admitted to the turbine through a 20-in. throttle valve with the oil-operating mechanism located below the steam inlet so that no oil can leak onto the hot steam piping. From the throttle valve, the steam is led through two 14-in. pipes to the ends of the steam chest, which is located on top of the cylinder. Seven control valves operated in series by a bar lift admit steam through bushings of the diffuser type to the nozzle inlet.

The control valves are actuated through an oil relay system by a governor of the hydraulic type, which consists essentially of an impeller, mounted on the turbine shaft, which discharges oil at a pressure varying as the square of the speed. The blade path is composed of an impulse element of the Curtis type and 13 stages of reaction blading. Steam is admitted to the impulse element through the first six control valves. The seventh valve admits steam directly to the reaction section and is essentially an overload valve.

The cylinder casing is of cast carbon-molybdenum steel. The rotor is a forging of nickel-chromium-molybdenum steel, and has a drum diameter of 22 in. The length of the unit between bearings is approximately 10 ft. The blades are made of stainless steel and the largest ones are approximately $5^{1}/_{2}$ in. high.

When operating at 3600 rpm, the peripheral speed of the blades is 532 ft per sec. The turbine and generator rotors are solidly coupled together and the unit is equipped with a motor-driven turning gear which will revolve the spindle at 5 rpm.

PIPING

The principal problem in connection with the piping installation is that produced by the temperature of the steam. This will normally be 900 F, but it may go as high as 925 F at times. The pressure in the main steam line will be 1200 lb per sq in., and in the feedwater lines will be as high as 1600 lb per sq in.

The factors of time, temperature, and stress and their effect on the behavior of metals have been given consideration for some years. In addition to these factors, the composition of the metal and also the character of the atmosphere surrounding it must also be considered. In order to obtain more information about the behavior of various materials in contact with high-pressure, high-temperature steam, the A.S.M.E. Research Committee is guiding some studies now being undertaken at Purdue University under the supervision of Dean A. A. Potter.

In refinery work where sulphur is present, use is made of an alloy containing from 4 to 6 per cent chromium. This same material will not necessarily be entirely satisfactory under high-temperature-steam conditions. Some metallurgists feel that molybdenum should be used and others tungsten. For our piping, we are proposing to use carbon-molybdenum steel containing approximately $^1/_2$ per cent molybdenum. Similar material will be used for the steel castings in the high-pressure turbine shell and also in the valve bodies and corresponding equipment.

It is of interest to note that most of the valve manufacturers are using stellited seating faces and that the seat rings on the high-pressure, high-temperature valves are welded in. Most of the valves will be welded into the pipe lines and the piping itself will be almost entirely welded. The only flanged joints will be those which must be broken from time to time in order either to make turbine inspections or do some similar work.

PRESSURE REDUCER AND DESUPERHEATER

When the new high-pressure turbine is operating and delivering steam to two low-pressure turbines, it will be fundamentally a single cross-compound unit having a rated capacity of 107,000 kw. If the unit were simply operated in this manner, the loss of the high-pressure turbine or its generator would immediately involve the loss of the other two units, and a considerable amount of generating capacity would immediately be lost to the system.

In order to prevent the loss of so much generating capacity, we are providing a by-pass around the high-pressure turbine, Fig. 4, which will be designed to pass sufficient steam from the high-pressure boilers to operate the two low-pressure turbines in case of an outage of the high-pressure turbine. This by-pass arrangement consists of a quick-opening valve, a reducing valve which will reduce the pressure from 1200 to 260 lb per sq in., and a desuperheater which will reduce the temperature from 900 to 600 F, Fig. 5.

The quick-opening valve will normally be closed, but in case of an outage of the high-pressure turbine it will open wide automatically in less than one second and will provide a continuous and uninterrupted supply of steam to the low-pressure turbines.

The pressure-reducing valve and desuperheater are necessary in order to supply the low-pressure turbines with steam of the proper pressure and temperature.

BOILER-FEED PUMPS

The Worthington Pump and Machinery Corporation is at present building three 6-in., six-stage boiler-feed pumps of the centrifugal type which are to be driven by 1500-hp General Electric turbines.

The pumps are designed to handle water at 380 F, and with a suction pressure of 275 lb per sq in. will pump 1200 gpm at a discharge pressure of 1600 lb per sq in. Two pumps will have sufficient capacity to handle full load on the high-pressure unit, and the third pump will be a spare.

The pumps will be direct connected to the turbine drives and will operate at 3500 rpm, and the turbines will use steam at a pressure of 250 lb per sq in. and a temperature of 600 F. The turbines will operate with a back pressure of 10 lb per sq in. and with extractions at 30 lb per sq in. Both the exhaust and extraction steam will be used in closed heaters for feedwater heating. The use of auxiliary turbines of this type is rather unusual, since in most stations using the regenerative cycle steam for feedwater heating is obtained by bleeding the main units.

Our present turbines have only one point of extraction and this is already being used to heat the feedwater to approximately 200 F. Since it is practically impossible to provide extraction openings on a unit already built without them, we felt that the best way to obtain a cycle equivalent to two additional extraction points on the low-pressure units would be the use of back-pressure extraction turbines which drive the high-pressure feed pumps.

Since something over 1 per cent of the energy generated in a 1200-lb steam cycle must be used for pumping feedwater, these auxiliaries are large enough to provide sufficient exhaust heat to raise the temperature of the feedwater to 350 F under normal conditions.

FEEDWATER HEATERS

With our present arrangement of equipment, condensate is pumped from the hot well through the thirteenth-stage extraction heater and delivered to the present boiler-feed pumps at 200 F, Fig. 4. These feed pumps raise the pressure to 325 lb per sq in. for the boilers. With the new arrangement of equipment, the water from the present boiler-feed pumps at 325 lb per sq in. and 200 F will be passed through a series of four feedwater heaters by which the temperature will be increased to approximately 350 F, and at this temperature will be delivered to the new high-pressure feed pumps.

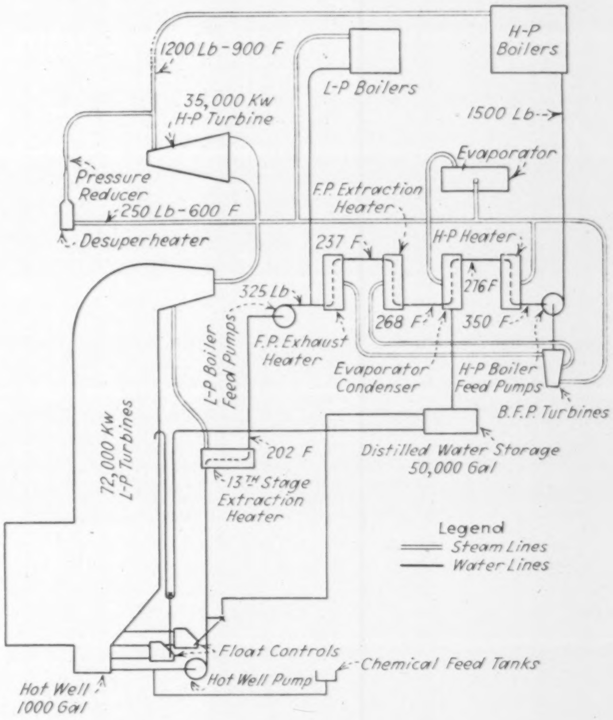

FIG. 5 PRESSURE REDUCER AND DESUPERHEATER

(Schematic arrangement of the quick-opening valve, the pressure-reducing regulator, and the desuperheater, which will be used as a by-pass around the main turbine to supply steam at the proper pressure and temperature from the high-pressure boilers to the low-pressure turbines.)

The first of the four heaters takes steam at a pressure of 10 lb per sq in. from the exhaust of the boiler-feed-pump turbines. The second heater is supplied with steam at 30 lb per sq in. from the extraction of the boiler-feed-pump turbines. The third heater receives steam from the evaporator, and the fourth heater receives steam at 260 lb per sq in. from the exhaust of the high-pressure turbine.

This arrangement of closed-type heaters makes a quite simple system of feedwater heating, since there are no water levels to control, the operation is entirely automatic, and the amount of heating depends entirely upon the heat head available at each heater.

MAKE-UP WATER

In any steam cycle using surface condensers there is always a certain loss of steam or water through leakage, soot-blowing, boiler blowdown, or changing the water in the boilers. In our cycle we assume that these losses will amount to approximately 2 per cent, and this amount of make-up water will be distilled by evaporators. These evaporators are similar to closed heaters in design and operate like a boiler when supplied with steam at a sufficiently high temperature.

In our case, the steam supply will be at a pressure of 250 lb per sq in. and a temperature of 600 F, and the water to be evaporated will be treated water from a cold intermittent-process lime and soda softener. Chemically softened water such as we are now accustomed to use for make-up has a hardness of three-fourths of a grain per gallon and the total soluble salts will run at least 20 grains per gallon.

Distillate from the evaporators will be of zero hardness and the total solids will not exceed $^1/_{10}$ of a grain per gallon. This means that the purity of the make-up water is increased at least 200 times by the use of the evaporators.

BOILER-WATER CONDITIONING

The use of almost chemically pure water in the power-plant steam cycle does not of itself solve all the water problems. Due to the fact that the pH value of neutral water decreases as its temperature increases within the temperature range in which we are dealing, it follows that serious corrosion difficulties would arise with both iron and copper. This could probably be attributed to small traces of oxygen which are carried in solution in the water, if we tried to operate with chemically pure water.

Experience in various power stations has indicated the desirability of maintaining higher pH values of the water by the use of various chemicals. For instance, we shall expect to operate the boilers with a concentration of 2 to 5 grains per gallon of sodium hydroxide. If a boiler should contain less caustic than this, more will be added, and if the concentration should increase above this amount, it will be reduced by blowdown.

This concentration of sodium hydroxide is considered sufficient for the protection of boiler metal against corrosion, but in order to prevent embrittlement of the boiler metal, it will be necessary to have a sulphate concentration at least three times as great as the caustic concentration.

Sulphate occurs naturally in the water around Cincinnati and ordinarily does not have to be added to the boiler water. Since we shall be using distilled water, however, we shall have to add sodium sulphate to provide the necessary protection for the metal against embrittlement.

In order to counteract any traces of free oxygen which might be dissolved in the water, we shall add to the condensate a small amount of sodium sulphite. The sulphite combines with free oxygen to form sodium sulphate, so that there is a double advantage in the use of sulphite: First, it combines with any traces of free oxygen and thus prevents corrosion; second, the sulphate formed by the combination acts as an inhibitor of embrittlement.

A certain amount of raw river water will leak into the condenser hot-wells through the condenser-tube fastenings. In order to neutralize the hardness which will be added to the water in this way, we shall feed sodium phosphate into the system. The phosphate will react with any calcium or magnesium salts which enter the boiler to form an insoluble phosphate, which will not cling to the heating surface, and in this way scaling is prevented.

These chemicals will be added by continuous feeding into the hot-well pump suctions in order to increase the pH value of the condensate and protect as much as possible the piping and the closed heaters.

The water conditioning will be supervised by Hall Laboratories, of Pittsburgh.

This may seem like the addition of a large amount of chemicals to the boiler feedwater, but as a matter of fact the additions are rather small and the maximum concentration of salts which we would expect to have in the boiler would be in the neighborhood of 500 ppm or approximately 30 grains per gallon. This concentration is not greatly in excess of the amount of salts which are ordinarily carried in the Cincinnati drinking water.

CONCLUSION

In presenting this picture of our new generating unit, I have had in mind not so much a description of the physical equipment as a summary of the principal engineering features involved. If we consider only the engineering developments of the past six years, which have made certain features of this installation possible, we shall find that they will be no small part of the present design.

For instance, the coal will be pulverized without predrying. The coal will be burned at a rate per unit of furnace volume at least four times as great as it is in our furnaces at Columbia power station, which were installed in 1925. Fly ash will be recovered from the flue gases by an electrostatic system, which, while not unknown six years ago, was then almost prohibitive in cost.

The arrangement of heating surface in a boiler unit so that the superheat can be varied without regard to load is a recent development. The design of superheater, piping, and turbine for a steam temperature of 925 F has only been made possible by recent metallurgical developments.

Advances in the technique of welding in recent years have made possible the use of continuous-tube superheaters and economizers; the use of high-pressure boiler drums at a reasonable cost; and the erection of a high-pressure piping system without prohibitively costly joints. These advances have also simplified the design and have greatly improved both valves and fittings.

Large high-speed turbogenerators, such as the one to be installed, are also dependent upon improvements made by the steel companies in turning out large forgings. These forgings have to meet rigid specifications which a few years ago could not have been met.

We have continued to increase our knowledge of the chemistry of boiler-water conditioning and can now reasonably anticipate the water and chemical problems.

When one considers the features of this generating unit and compares them with those units of six years ago, he cannot help but be greatly impressed by the large number of engineering developments which have taken place during the past six years.

ECONOMICS *and* TECHNOLOGY

By RALPH E. FREEMAN

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THOSE interested in studying the influence of technological progress upon our economic life will find no book more instructive and stimulating than the treatise recently written by Prof. Ferdynand Zweig, of the University of Cracow. It provides an excellent background of theory and methodology for those who would undertake investigations into specific industries. "Economics and Technology"[1] is not mathematical nor statistical in character; it deals with general tendencies and those elements of the problem which are representative of the majority of cases. Such a work has long been needed in this field.

Professor Zweig begins by defining economics and technology and then discusses technological progress, dividing it into three categories—progress in productivity, progress in quality, and progress in novelty. In the preface he writes:

> I wish to lay stress on the analytical part of my work. In it I endeavor to show that what we call technological progress is really a complicated set of phenomena, that differ not only in form and scope, but also in their cause and effect, and the importance to be attributed to them. . . . Mechanization creates a different set of problems from rationalization, industrial organization, or industrial psychology. Progress resulting in saving of capital has a different economic significance from progress resulting in a saving of labour. Development that aims at the production of goods that are positively productive must be measured and valued from a different angle from the production of goods that are of a destructive character. All these distinctions have to be kept well in mind, for if we do not take into account the vast and essential differences between such factors, the conclusions that we arrive at will be lacking in perspective and miss the essential point.

While part I is analytical, part II is theoretical, dealing with technological unemployment and the problem of compensation—that is, the problem of absorbing the technologically unemployed through subsequent expansion of output. This problem is viewed from three aspects: (1) From the aspect of the particular branch of production in which the invention has been introduced; (2) from the aspect of the national economy; and (3) from the aspect of world economy. Although there is little that is new in the economic theories somewhat sketchily propounded here, yet the method of approach and the classification of the various factors involved throw new light on this whole problem and cannot fail to be illuminating to any student of the subject. In the latter part of chapter 1, part II, the author develops the thesis that "the natural increase in population is a dynamic factor in economic life, since it widens its dimensions and facilitates the absorption of technological unemployment in periods of intense technological progress."

In this theoretical section of the book there is also considered the influence of technological progress on the distribution of incomes. Under what conditions does the major part of the increased productivity go, to the wage earner, the capitalist, or the land-owner? Here again the method of approach is suggestive. Though some statistics are presented, the author's conclusions are supported chiefly by reasoning from the nature of the phenomena—the elasticity of the demand for the different elements of production, the character of the commodities affected, the influence of monopoly, and so forth. Regarding monopoly, the author concludes "that economic monopolization increases the share of capital in the national dividend, thus intensifying the tendencies resulting from technological progress."

Part III is sociological in character. Here the author discusses the sources of changing technique and its effect on economic freedom and the concentration of wealth. To many this will doubtless appear the most interesting part of the book. Technical advances lead to monopoly and monopoly accentuates the disturbances caused by such advances. While in a free competitive system the disturbances are mitigated by the automatic adjustment of prices, under a system of monopolistic restriction (which the author calls "autarchy") the compensating price adjustments are impeded and delayed. At the same time these restrictive conditions lead to a slowing down and final cessation of the technical progress which produced them. "Thus technological progress will meet its end at the hand of autarchy, for whose creation it is responsible." Professor Zweig does not, however, leave us with this pessimistic conclusion. After monopoly has done its worst in undermining the fundamentals of further economic development "there will come again a great liberal revolution which will strike a fatal blow at monopolies and change the direction and very purpose of technological improvement."

The remedies for technological unemployment are dealt with in part IV. Here the author reviews the principal remedies for unemployment, pointing out their difficulties and disadvantages. Because of space limitations, the discussion of this subject is necessarily inadequate. He is skeptical of the efficacy of "artificial" remedies such as currency experiments, public works, reduction of hours, and agrarian schemes. He says:

> We can see, therefore, from the above discussion the relative and limited nature of the application of artificial remedies. As a rule, a combination of a number of mild remedies gives a better result than the application of a single radical remedy, i.e., a remedy applied on a large scale. But even such a combination has its limits, since the defects produced by each one of those remedies are accumulated.
>
> Only natural remedies for unemployment give best and lasting results, for they have no onerous effects on the social economy. Amongst natural remedies, the internal and external liberalization of the economic system is of prime importance. Dissolution of cartels and monopolies is part of the process of liberalization, as of the equalization of incomes; it increases both production and employment. The removal of State reglementation as well as *the removal of obstacles in the international exchange of goods, capital and labour* helps to increase the volume of employment. The process of making economic life elastic, in the sense of allowing the proper working of economic automatism, is the best and least burdensome remedy for unemployment.

Professor Zweig, in conclusion, declares that the problem of the future is to change the course and direction of technological progress. Progress in the past has been chiefly quantitative in character, in the direction of saving labor, in the direction of increasing the amount of fixed capital in industry, thus lead-

(*Continued on page 599*)

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[1] "Economics and Technology," by Ferdynand Zweig, P. S. King, London, 1936. Cloth, $5\frac{1}{2} \times 9$ in., 252 pp., 10 s net.

One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

BECAUSE the editor of this section, who has abstracted the articles that have appeared in it since the establishment, in 1912, of the "Foreign Review" as it was then called, is on leave of absence, space devoted to the abstracts has been reduced.—EDITOR.

APPLIED MECHANICS

Flexural and Shear Deflections of Metal Spars

FIVE typical spars supplied by aircraft firms were tested within the elastic limit as simply supported beams carrying one or more concentrated lateral loads. They were also tested with combined end loading and lateral loading, with various ratios of bending stress to end load direct stress; at a selected ratio each spar was tested to destruction. The apparent values of the effective flexural stiffness *EI* and the elastic-shear constant *r* were determined.

The results of these tests have been compared with a large number of similar routine tests. It is concluded that spars may, in general, be divided into three categories according to the material of manufacture: (1) Hardened and tempered steels, (2) relatively softer steels, and (3) duralumin. There is no appreciable variation in *EI* in category 1, but there is an appreciable reduction in the value of *EI* toward failure in categories 2 and 3, and this still leaves the problem of how to allow for this reduction when calculating the failing load of the whole spar, as built into an airplane, from tests on a relatively short specimen. As, however, most spars at present belong to category 1, further research is not warranted.

It will be possible to make assumptions, when dealing with spars in categories 2 and 3, sufficiently conservative to cover the uncertainty introduced by variations in *EI* when bridging the gap between the test specimen and the spar as built into the airplane. (I. J. Gerard and H. Boden, British Bureau of Scientific Research, Air Ministry, Reports and Memoranda No. 1671, June 7, 1935, 14 pp.)

ENGINEERING MATERIALS

Adhesives

ADHESIVE joints are not only light in weight and occupy a negligible amount of space, but many times their use permits an assembly which otherwise could not be made. Recent improvements in adhesives have so greatly increased their strength that it is now possible to realize tensions of one-half ton per square inch in air-dried joints and almost a whole ton where the adhesive is applied dry and then melted by heat.

There are two methods of using adhesives to make a joint. One is by drying at room temperature or a little above it. The other is a process in which sufficient heat is used to melt a dry thermoplastic adhesive previously placed between the surfaces to be joined. The mechanism of adhesion (mechanical adhesion and molecular adhesion) is explained as well as the structure of resinous adhesives.

An idea is often advanced that adhesives adhere to metal surfaces by first visibly etching them in order to secure a mechanical bond. This idea was investigated by comparing the adhesion obtained on gold with that obtained on the more chemically active surfaces of copper, steel, and aluminum. The joint strengths were of the same order in each case, which indicates that on these metals at least there is no necessity for an adhesive to etch the surface in order to obtain a good hold. (John B. DeCoste, in *Bell Laboratories Record*, vol. 14, no. 10, June, 1936, pp. 330–332, 2 figs.)

INTERNAL-COMBUSTION ENGINEERING

Characteristic Features of Heavy Fuel Oil With Constant Atomization and Limited Maximum Pressure

FOR proper functioning of a heavy-fuel-oil engine with direct injection, it is necessary to have constant atomization in order to obtain complete combustion without smoke or residues and to operate with a limited maximum pressure. Since the fuel does not ignite at the instant of its injection, but with a certain lag, which depends on its chemical composition, it is necessary to begin injection before dead center with a certain angular lead γ determined by the requirement in regular operation, so that the increased pressure resulting from combustion at constant volume of a quantity of combustible introduced at the instant that ignition takes place at the dead point.

Let V_m be the clearance volume, V the volume swept by the engine piston after the dead center, T_m the absolute temperature at dead center, T the absolute temperature for volume V, v the volume swept by the fuel-pump piston beginning with the moment where the engine piston is at dead center, δ the density of the fuel. Q its heat capacity, ω the weight of air in the swept volume per cylinder, and c_p the specific heat of the air at constant pressure. If we neglect the variation of ω due to the introduction of the fuel and variation of c_p, we shall have at each instant

$$T = T_m + \frac{vQ\delta}{\omega c_p}$$

For isobaric combustion, it is theoretically sufficient that

$$\frac{V + V_m}{V_m} = \frac{T_m}{T}; \quad \frac{V}{V_m} = \frac{v\delta Q}{\omega c_p T_m}$$

In other words, the piston of the fuel pump must have a motion similar to that of the engine piston and this determines the angle α of the injection of the fuel. Since the droplets of fuel take a certain time to burn, it is necessary that the real angle of injection β be less than α, the difference between the two decreasing with the improvement in atomization. If the angular velocity ω changes, it is necessary to maintain constant the velocity ν of the injection of the combustible, that is atomization. If σ is a section of the injector, q the total volume of the fuel introduced after dead center, and c the duration of the injection, we have

$$q = v\sigma t = v\sigma\beta/\omega$$

which shows that it is necessary that the section of the injector should vary in proportion to ω. On the other hand, if, when the angular advance of injection remains the same, ω decreases, the ignition of a constant weight p of fuel introduced before dead center will take place with an angle between γ and 0, and the temperature T_m at dead center will vary.

If we designate by V_1 and T_1, the dimension and absolute temperature of the swept volume for an angle γ, by K the ratio between the specific heats, and by C_v the specific heat of air at constant volume, it will be easy to see that T_m varies between two extreme limits:

$$T_1 + \frac{pQ}{\omega C_v} \text{ (ignition at dead center)}$$

$$T_1 + \frac{qQ}{\omega K C_v} \frac{(V_1/V)^K - 1}{(V_1/V) - 1} \text{ (zero ignition lag)}$$

and the pressure at dead center will vary correspondingly.

Similarly, if the angle β remains constant and the combustion ceases before α, the combustion will no longer be isobaric, and the pressure will tend to rise, the theoretical maximum thereof being obtained for an instantaneous combustion ending at the angle β. In particular, the decrease of ω carries with it a corresponding decrease in turbulence, and is an essential factor when it comes to the velocity of combustion. (P. Dumanois, *Comptes Rendus des Séances de l'Académie des Sciences*, vol. 202, no. 17, Apr. 27, 1936, pp. 1409–1411)

Cooling of Aircraft Engines

COOLING of aircraft engines involves the exposure of a large heated surface to a stream of air, a process which involves the expenditure of power owing to the viscosity of air. Until recently, it appeared that this fact imposed an intractable limit to the speed of aircraft since, whereas the heat transfer only varies directly as the speed of the air over the surface, the power expenditure varies as the cube. Thus even though the exposed surface be adjusted until only the required heat transfer is effected, the power expenditure increases as the square of the speed. This fact and the recent increase in the speed of airplanes has brought the question of cooling drag into prominence and forced the application of the principle of low velocity cooling. An analysis of the performance of a cooling system enclosed in a duct was therefore required in order to guide further research and design.

The theory of the ducted radiator has been developed and a basis of calculating the drag is provided. The effects of compressibility have also been investigated.

This report demonstrates that power expended on cooling does not increase with speed for a properly designed ducted system but that, owing to recovery of waste heat, a thrust may be derived at speeds of the order of 300 mph. Attention is also drawn to the importance of the momentum of the exhaust gases at high speeds of flight. (F. W. Meredith, Bureau of Scientific Research, Great Britain, Air Ministry Reports and Memoranda No. 1683, Aug. 14, 1935, 12 pp.)

SPECIAL PROCESSES

Hydrogen Cooling of Machines

INTEREST in the application of high-temperature high-pressure turbines superposed on existing generating units has increased rapidly during the past few years. This type of steam turbine is easier to build for a speed of 3600 rpm than for a speed of 1800 rpm, because smaller masses and dimensions can be used. As a result, development of this type of turbine has made it necessary to build 3600-rpm generators for ratings much larger than previously were considered feasible.

The largest 3600-rpm turbogenerator unit now in service in the United States is rated at 22,500 kva, 18,000 kw, at 0.8 power factor. Careful analysis of fundamental test data and operating experience, and a concentrated effort to coordinate properly the proportions of both and structural parts and to utilize materials more effectively, have made it feasible to build air-cooled 3600-rpm generators for ratings up to 62,500 kva, 50,000 kw, at 0.8 power factor, which will be comparable in cost and reliability with similar large 1800-rpm units.

The rotor of a large 3600-rpm generator necessarily operates at very high peripheral speeds; consequently, the windage, friction, and ventilation losses are inherently high, and they form a large proportion of the total losses. It is apparent that the 3600-rpm turbogenerator offers the greatest possibilities for reduction in losses when using hydrogen as the cooling medium.

One of the first turbogenerators designed for, and operated with, hydrogen cooling was rated at 9375 kva, 0.8 power factor, and 3600 rpm. This machine was built by the Westinghouse Company. Until the latter part of 1935 and the early part of 1936, however, no actual orders were placed for the construction of such machines. Outstanding among 3600-rpm hydrogen-cooled turbogenerators recently purchased are the 58,725-kva, 50,000-kw, 0.85-power factor unit of the New York Edison Company and the 43,750-kva, 35,000-kw, 0.80-power factor unit of the Union Gas and Electric Company, of Cincinnati, Ohio, and the 50,000-kva, 0.90 and 1.0-power factor unit of the West Penn Power Company. Generators that have been built, or are being built, with ratings of 18,750 kva or more, are listed in Tables 2 and 3 which appear in the original article. (C. M. Laffoon, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., in *Electrical Engineering*, vol. 55, no. 6, June, 1936, pp. 703–709, 5 figs.)

VARIA

Assistance to Inventors

GENERALLY speaking, industry is alive to the need for new ideas, but this does not necessarily smooth the path of the inventor. In the first place, the amateur may be ignorant of the best way to exploit his device, and even when his suggestion is sound, the fact that its adoption may mean an entire recasting of the production program may prove an almost insuperable obstacle to its commercial exploitation.

The object of the Merseyside Society of Inventors, 67 Moscow Drive, Liverpool, is to bridge the wide gulf between industry and the inventor, whatever be its cause, and, on the one hand, to do so by obtaining from the manufacturer full details of his plant, and from the inventor equally full information about his new ideas. In regard to the latter, technical advice will also be available, as well as facilities for making models and practical tests, and later on patenting the invention.

The invention is investigated by a committee, of which the inventor himself is a member, this routine, it is held, in itself simplifying commercialization, since any device which survives must be of some value. This point has already been appreciated by manufacturers, who have been helped to find further capital where such a course is necessary for the adoption of an invention. Further, the inventor is assisted in finding manufacturers for his goods in those cases where he wishes to control the sales himself.

The society seeks to become a clearing house for approved inventions, so that time-wasting ideas may be discouraged and those worthy of encouragement assisted. (*Engineering*, vol. 141, no. 3667, April 24, 1936, p. 457)

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities

Usurpation of the Term Engineer

To the Editor:

For 100 years or more the man engaged in the operation and maintenance of a steam plant or steam engine has been known as an engineer. To designate his specific line a prefix was used, and thus we have stationary, marine, and locomotive engineers.

It is of no consequence whether the name engineer is correctly chosen (according to interpretation of Webster or of other authorities). These men have been known as engineers and will continue to be so known by the American populace.

In addition to the operating engineer others are designated as mechanical, electrical, or chemical engineers. It is generally taken for granted that the man so designated is engaged along these lines and has had training, experience, and probably a college degree to justify such title.

A number of organizations, organized and incorporated in accordance with law, are known as engineering societies or engineers' associations, having in their membership engineers of various branches. For instance, The American Society of Mechanical Engineers was organized April 7, 1880, and incorporated in 1881. The National Association of Stationary Engineers (later changed to National Association of Power Engineers) was organized October 25, 1882, and duly incorporated.

At the present time professional engineers in several states are, through legislation, attempting to prevent any one except a man with a professional engineers' license from using the title engineer; and it is even suggested (see page 521, August, 1936, Mechanical Engineering) that the other "engineers" who no longer are allowed to use their own designation set out to find themselves a new one so as not to interfere with the professional engineer.

The federal government and a number of state and city governments have in force, laws, regulations, and ordinances providing for the granting of engineers' licenses to men who can qualify as regards experience, training, and the passing of examinations for such positions as those of stationary engineer or marine engineer.

It appears quite doubtful that these regulations should be repealed in order to allow the professional engineer to be put "in responsible charge of the plant." Neither does it appear reasonable that the word engineer should be eliminated from such use.

If a professional engineer has responsible charge of a steam plant in a state or city where a license as engineer is required, he must naturally fulfill the requirements and pass the examination as any other applicant in order to obtain a license "to have responsible charge" of the steam plant, in other words, he must have the required qualification and license as a chief engineer.

In regard to the term engineer it seems that the men who have been universally known as such keep their title and the professional engineer, who is raising the objection, is the one to set out to find a new and more suitable designation for himself if he is not satisfied with "professional engineer."

Einar Winholt.[1]

Social Security

To the Editor:

In view of the palpably "New Deal" outgivings now appearing fairly regularly in Mechanical Engineering under the guise of "a series of reviews of current economic literature affecting engineering, prepared by members of the Department of Economics and Social Science, the Massachusetts Institute of Technology, at the request of the Management Division of The American Society of Mechanical Engineers," may a plain, ordinary member have some little space to pick a flaw?

In the review of "Social Security in the United States," by Paul H. Douglas, pages 447–448 of the July issue, Professor Shute seems to approve heartily of the federal unemployment-insurance scheme, although, as he remarks, it is "intended generally to protect organized labor" and that "large groups of wage earners are excluded from the plan," including agricultural workers and, among other classes not mentioned by him, domestic workers, and that not inconsiderable portion of our population that still manages in one way or another to shift for itself.

It does not seem to occur to Professor Shute, however, that this is rank class legislation, enacted at the behest of industrial labor-union leaders, and utterly unjust to all other elements of the population.

The taxes to pay for unemployment insurance must inevitably increase prices of manufactured goods and hence will be paid by the general public, only a small fraction of which will share in the benefits. For example, the agricultural laborer or the independent farmer working a 70- to 80-hour week in a freely competitive occupation may, in effect, be required to support in idleness industrial unionists perhaps on strike for a closed shop and a 30-hour week.

May we not hope that one "of the vagaries of the Supreme Court" to which Professor Shute adverts, will be to quash this grossly inequitable, as well as unconstitutional, law?

Geo. H. Gibson.[2]

The Future Is in Doubt

To the Editor:

Ralph E. Flanders, as president of The American Society of Mechanical Engineers, wrote in a circular letter to the members of the Society:

"The future of the profession hangs in the balance. The future is in doubt for the social order which has been built upon the work of the engineer. The times demand the development and application of engineering statesmanship."

Is Mr. Flanders merely an alarmist, or has he sounded a warning which we shall be wise to heed? And what does he mean by engineering statesmanship?

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[1] Moline, Ill. Mem. A.S.M.E. and N.A.P.E.

[2] Geo. H. Gibson Company, New York, N. Y. Mem. A.S.M.E.

From all the discussion of the depression and its causes, two facts emerge clearly: One is that we can now produce all we need—enough for every one to have abundance; and the other is that it is our inability to manage our social economy which stands between us and the abundance that we might have.

To say that a factory of even a few hundred employees could by any possibility succeed under mere supervision with inadequate management would be absurd; yet it seems to be assumed without question that the affairs of the nation and of every subdivision of it can be brought to a satisfactory issue by supervision with little or no management.

This question is not one of communism versus fascism, of socialism versus capitalism, of collectivism versus individualism, or even of the New Deal versus the Old Deal. It is a question of the efficient management of our collective affairs.

Fifty-three years ago Frederick W. Taylor began the development of improved management in industry. His work and that of the others of that first generation of management engineers, the Gilbreths, Gantt, Barth, Harrington Emerson, and others, is well-known. It was natural to put engineers in charge of production, and engineers found that production had to be managed. They did not begin as specialists in management, but because they were confronted by problems of management for which they had to find the solutions, they applied to them engineering methods with results which were most fortunate for the world.

These pioneer management engineers and those who have succeeded them have developed a body of theory and practice which has thoroughly proved its value by application over a wide range of industry. It is therefore surely worth while to inquire whether this special knowledge of management is limited in its application to industry, or whether it offers us any help in our present difficulties.

While the science of management had been applied practically exclusively to production until 1920, the depression of 1920 and 1921 showed the necessity for improving the management of distribution and general administration; and since then much work has been done to that end. It has revealed no new principles, not even any new techniques, but simply the application of well-known principles and techniques to new problems. In short, the experience of 53 years indicates that *management* is *management* and is governed by the same laws and is operable by the same technique, regardless of what is managed.

Engineers who have delved beneath the superficial methods which form the surface of up-to-date efficient management have developed a body of principles which, until the contrary is proved by trial, we are justified in assuming to be universal in their application. This body of theory and practice, on the subject of management is thoroughly applicable to our present critical problem. However, it is not being adequately used because even its existence is unknown to most people and because those who have it seem, in the main, to be unaware of its applicability in any larger field than that in which they are now using it.

The present depression has shown how little even the best management of even the largest corporation can withstand the general social economic conditions for the reason that we have again reached the point, already familiar to management engineers, at which the method of further progress is to apply the principles of management to a wider area, in this case society in general.

The engineer is, by the nature of his profession, a prime mover of progress, and his professional habits and methods of thought fit him also to be a stabilizer. He is likely to be greatly needed in both capacities.

Management engineers well know the difficulties which have to be overcome in installing up-to-date industrial planning, even in a small business. Many workmen think that every attempt to record the progress of orders is a wicked attempt to "get something on them" and deprive them of their jobs. Some foremen resent being required to exercise forethought, instead of merely taking things as they come. Certain superintendents think that planning undermines their authority. Directors who have been brought up to regard continual improvisation as the proper method sometimes consider every cent spent on planning as wasted and cannot be convinced, even by cost reports, that it saves far more than it costs. Also the conservatives are likely to say to the engineer, "We have done it that way for forty years, so it must be right."

Management engineers, therefore, thoroughly understand that installing a planned economic order in the United States is going to be a long, highly controversial, difficult, and arduous process.

Since every failure and every error anywhere about the plant interferes with plans, planning can be developed only step by step with general improvement in management, and since the development of planning is highly controversial, it is best, if possible, to follow an opportunistic policy.

Those who have not given the matter any particular attention will be surprised to learn the extent to which we are already planning; but these many attempts at planning are not sufficiently connected and therefore lack proper coordination. It is to be hoped that social-economic planning, in whatever measure it may come in this country, will be a natural evolution from such beginnings, rather than that some "five-year plan" should suddenly be imposed on the country by revolutionary, or even near-revolutionary, procedure. Engineers can contribute to that desirable end by making themselves heard in the matter and giving the country the benefit of their knowledge of planning derived from 53 years of experience in industry.

The opponents of planning seem to understand by it highly centralized control worked out in detail. Management engineers know by experience that such planning will not work. Attempts were made at first to plan industrial operations by that method, but it was necessary to change the methods and decentralize the planning. It is to be hoped that engineers will be able to keep their friends, the reformers, from repeating past mistakes.

Engineers have seen the movement for improved management, gain in power and extend itself into new and wider fields. Also they have seen it favorably received, on the whole, by industrialists. Nevertheless, they are obliged to confess that, after 53 years of effort, average industrial management is still far from good. In the face of these facts, it cannot be expected that the improvement of social-economic management can be anything but a long and arduous process.

I desire especially to bring this problem to the attention of teachers of engineering, because, even if we, in our generation, accomplish more than can reasonably be expected, it will still be the students in our classes who will have to carry the matter through to a successful conclusion. It will be, I expect, *the* problem of their generation. We owe it to them to prepare them for it to the best of our ability.

The length of the task should not discourage us. Experience in industry shows that a big job of improvement of management takes a long time; but it shows also that valuable gains may be made almost immediately and that other valuable gains may be made at frequent intervals thereafter. The journey will be long, but the route will grow more and more pleasant all along the way.

At the same time, the need is urgent. If we neglect the problem, we shall often be overtaken by crises in which something must be done and done at once. The case is then one of kill or cure; and emergency measures, taken in haste and without adequate knowledge, sometimes kill instead of curing. Neglect is therefore dangerous in the highest degree.

Between this danger on the one hand, and the "intolerable pain of thinking" on the other, a large part of the civilized world has called in dictators to think for it. When a people sets up a dictator, it gives up its liberty, and thereby loses the power to hold its government responsible. History shows that an irresponsible government immediately begins to degenerate and that sooner or later it becomes oppressive misgovernment and exploits the very people whom it was intended to serve. If we give up our liberty for the sake of immediate economic benefits, our latter state will be worse than our first. The horrible fate which confronts us is, therefore, that we shall be obliged to manage our own affairs.

At the same time, the road to efficient social-economic management is long, arduous, and at least potentially dangerous. Since we are probably destined to undertake the journey, it will be lamentable if the fund of knowledge which can be derived from 53 years of study and experience in the improvement of industrial management, should be neglected.

If engineers express themselves with a reasonable degree of tact, they will be heeded. They must be careful, however, to avoid an air of superior wisdom; and above all, they must not give the impression that they are seeking to make themselves a ruling caste—"technocrats" in the catch phrase of yesteryear.

GEORGE H. SHEPARD.[3]

Hütte's Ninetieth Anniversary

TO THE EDITOR:

This year marks the ninetieth anniversary of the famous engineering handbook, the German publication Hütte. It is an event that deserves more than passing notice, for Hütte is not only one of the outstanding publications in engineering literature, but so far as the writer knows, it is the oldest of the engineering handbooks. As well as being the oldest, it ranks among the best. In its pages can be found information that is available in no other place. Notwithstanding that it is in the German language, a great many American engineers have found it exceedingly useful.

The fact that the Vereines deutscher Ingenieure is an outgrowth of the Society Hütte renders the ninetieth anniversary of the society all the more important.

ROBERT T. KENT.[4]

An Explanation

TO THE EDITOR:

The article "Review of Aeronautics," MECHANICAL ENGINEERING, July, 1936, contained the following misleading statement: "In 1935 the six-engine 32-ton Latécoere 521 (6 × 860 hp) flying boat which unfortunately crashed before being put into service."

Papers in this country have published the fact that the French flying boat made a successful flight from France to Pensacola through the South Atlantic Ocean, but was upset and damaged by a storm when anchored in front of the naval air station. The plane was easily repaired and will fly again shortly.

NORBERT CHAMPSAUR.[6]

TO THE EDITOR:

The text of the article referred to by Major Champsaur was intended to convey the meaning that the Latécoere 521 flying boat crashed before being put in the scheduled air line service carrying passengers or air mail. It is unfortunate that the wording was such that any other meaning could have been construed.

RICHARD M. MOCK.[7]

Desired Characters of Surface Finishes

TO THE EDITOR:

Few actual data are presented in Mr. Kline's paper;[5] instead it consists almost entirely of description and theorizing on a wide variety of items. This material falls into three classes:

(1) Points which are in accord with existing data and information.

(2) Theories which can be contrasted with equally plausible but opposite theories.

(3) Material which is contrary to existing data and information.

SOUND POINTS

Among the sound points are those concerning the effect of surface finish on static and running friction, the fact that viscosity is not the only factor of importance in lubricants, and the fact that the performance of a surface rather than its visual appearance is of primary interest. It is obviously true that the size, direction, and shape of the irregularities of a surface are determined by the finishing operations, and these factors greatly affect the suitability of the surface for its use.

Another excellent point is the necessity of accurate geometry if the advantages of smooth surfaces are to be realized. Eccentricity, taper, and waviness of surfaces certainly affect run-in, wear, and life, particularly for smooth surfaces. This point can hardly be emphasized too strongly. In certain practical applications where the expected improvements were not obtained with smoother surfaces, it was found that the difficulty was due to distortion, inaccurate geometry, or waviness. From profile records of wavy machined surfaces it is evident that these irregularities may be more important than the fine-spaced irregularities which constitute the roughness of the surface. It seems quite certain that surface finish assumes greater importance as geometry and waviness are held to closer limits.

UNSUPPORTED THEORIES

(*a*) The theory is advanced that rougher surfaces are better lubricated and less liable to seizure and initial wear.

To the best of my knowledge, this point has never been substantiated by actual measurements. Since seizure and wear must come at points of high unit stress, it is just as reasonable to believe that these loads will be minimized by smoother surfaces which distribute loads over larger areas. The author mentions the well-known fact that clean, dry, smooth surfaces, such as Johansson gage blocks, adhere when "wrung together." With lubrication, the situation is different. Recently, a drop of fine spindle oil was placed on the working surfaces of a pair of Johansson blocks and the blocks were laid aside. One week later, sufficient oil remained on the surfaces to make it impossible to wring them together. I have no desire to take sides on the question as to whether smooth or rough surfaces are better lubricated, but it seems to me the theorizing is fully as plausible for the smooth surfaces. In any event, the matter can be settled by actual test.

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[3] Professor of Industrial Engineering and Management, Purdue University, Lafayette, Ind. Mem. A.S.M.E.

[4] Editor, Kent's Mechanical Engineer's Handbook, Verona, N.J. Mem. A.S.M.E.

[5] "Desired Characters of Surface Finishes," by J. E. Kline, MECHANICAL ENGINEERING, December, 1935, pp. 749–752.

[6] Air Attaché, Ambassador of France to the United States, Washington, D. C.

[7] Fokker Representative at Douglas Aircraft Co., Inc., Santa Monica, Calif.

(*b*) The theory is advanced that initially smooth surfaces are superficial as actual operating surfaces are much rougher.[8] Unfortunately, the profilogram used to support Mr. Kline's point was not a run-in cylinder as stated. The upper two curves of Fig. 2 are reproductions of Fig. 1 of Mr. Kline's paper. The third record is a profilograph taken by me on a new cylinder which had never been run. This represents a rather rough job of finish honing, and is obviously the same record presented by Mr. Kline. The fourth curve is that of a well-run-in automobile cylinder, and comparison with the first curve shows that it is considerably smoother than an excellent job of finish honing. From a knowledge of the finishing methods in use at the time the cylinder of curve 4 was originally made, it is quite certain that it was at least as rough as curve 2.

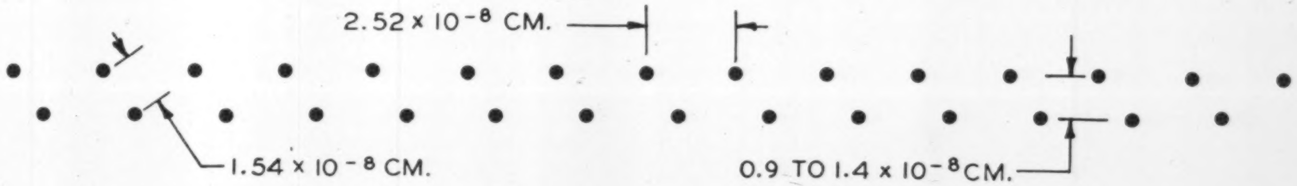

FIG. 2 DIMENSIONS OF TYPICAL HYDROCARBON MOLECULE

(Molecule dimensions approximately $1.5 \times 3.6 \times 35.3 \times 10^{-8}$ cm; carbon atoms of neighboring chains are 3.7 to 4×10^{-8} cm apart; hydrogen atoms are 1.8×10^{-8} cm from the carbon atoms.)

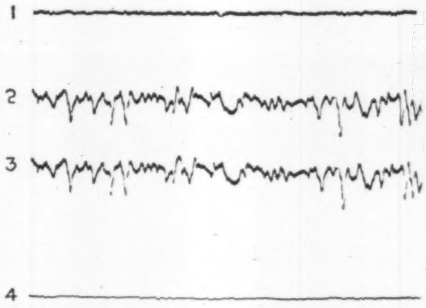

FIG. 1 PROFILOGRAPH RECORDS

From other records[9] of several worn cylinders, taken in both axial and circumferential directions, the obvious conclusion is reached that while very smooth running surfaces may be obtained under favorable conditions, the surfaces existing in actual operation vary widely, depending upon conditions of load, lubrication, and service.

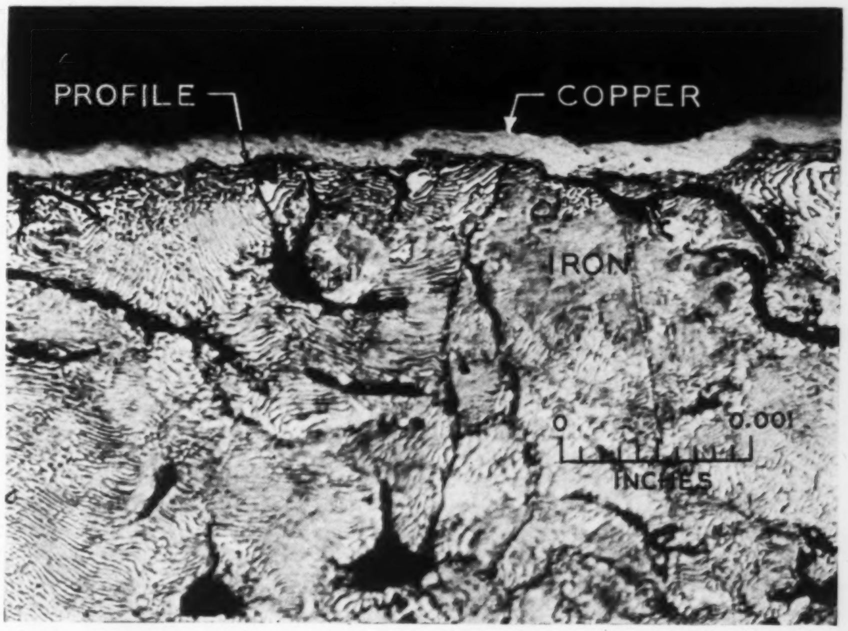

FIG. 3 TYPICAL SURFACE PROFILE ON CAST IRON

(Rough-honed cylinder—×1000.)

(*c*) It is implied that the appearance of a surface, particularly its ability for reflection, is misleading, both as to smoothness and performance. If surfaces can be held side by side for comparison, most individuals place a group of specimens *of the same type of finishing operation* in exactly the same order as the size of irregularities shown on profilograms. On the other hand, when surfaces of different types are judged (e.g., turned, milled, ground, honed, burnished, lapped, etc.) it is found that visual ratings vary tremendously. A single specimen in a group has been rated all the way from first to last place by different individuals in a series of specimens whose profilograms showed variations in the size of irregularities of at least 20 to 1. Many individuals will rate a dull appearing surface as smoother than a bright surface, but nine times out of ten the bright surface shows smaller irregularities on the profilograph.

An individual's ability to make proper visual comparisons of surface finish is greatly improved by correlating actual measurements such as profilograms with visual appearance, and a knowledge of the type of finishing operating represented. As in other observations, the human equation is not infallible, and large errors arise when new factors are introduced.

Summarizing this experience, I would agree with Mr. Kline that the appearance of a surface, particularly its reflecting qualities, is not an absolute guide to its smoothness. On the other hand, experience shows that under most circumstances, the reflecting quality is an excellent indication of smoothness, and that the exceptions to this rule are greatly in the minority.

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[8] There is another group of practical men who assert that initial finish is of slight moment since surfaces wear-in "smooth as glass."

[9] See, for example, "Wide Variations in Cylinder Finishes Revealed in Different Makes of Cars by the Profilograph," by E. J. Abbott, *Automotive Industries*, March 30, 1934, pp. 444–448.

As to the relation of appearance and smoothness to performance in operation, actual data are conspicuous by their absence.

UNSOUND POINTS

The discussion of molecular structure and the "ball bearing" theory of lubrication is contrary to known physical and chemical measurements. In the first place, molecular dimensions are from 100 to 10,000 times too small to play the rôles assigned to them by the author. For example:

Surface irregularities (from upper curve, Fig. 1 of paper), width 50–500 millionths inch; depth 5–20 millionths inch. Molecular dimensions (physical handbook), iron crystal (distance between atom centers), 0.0112 to 0.0116 millionths inch.

Measurements show that oil molecules are decidedly not globular as stated. Instead they are in the form of long strings, "rings," and other peculiar shapes. Fig. 2 shows a sketch of the carbon atoms in a typical paraffin hydrocarbon, $C_{29}H_{60}$. Associated with each of these heavy carbon atoms is a pair (with two extra at the ends) of light hydrogen atoms not shown in the sketch.

As indicated, this string is about 20 times as long as it is wide, and would hardly roll like a ball, even if it were of the right order of dimensions. Hence, it seems quite certain that the author's simple theory of flattened steel balls for metal and oil molecules is far from sound.

Crystal or grain dimensions in steel or cast iron are more nearly the size that the author had in mind. Fig. 3 shows a photomicrograph of the profile of a section of rough-honed surface. This was obtained by the well-known method of copper-plating, mounting, cutting, polishing, and photomicrographing. This covers a comparatively insignificant amount of surface, but several points are shown. These points, moreover, are substantiated by similar records on other specimens.

(1) Grains are considerably larger than surface irregularities, hence a fine finishing operation must actually cut through the grains of the material.

(2) There is often a tendency for the material to break out roughly near the edges of grain boundaries. It is believed that this is at least a partial explanation of the somewhat alternate smooth and rough spots on curve 2 of Fig. 1. It also indicates a relation between metallurgical characteristics and finish.

(3) The prominent surface irregularities themselves are very dull, being many times as wide as deep. The same effect is shown on profilograms when the actual dimensions are compared. Profilograms give the impression of sharp surface irregularities because the horizontal scale is compressed at least 50 times to allow more specimen to be recorded on a record of moderate size.

(4) Of course, crystal shapes are not globular any more than are the molecules. Instead, they are of irregular shape, nicely fitted together, with thin amounts of intervening material.

CONCLUSION

The author lists three conclusions:

(1) Making as an objective the obtainment of affinitive surfaces possessing more nearly "run-in" characteristics, rather than absolute smoothness.

(2) The importance of diametric precision relating to operating tolerances, and

(3) The consequent danger of having too smoothly finished surfaces when operated with insufficient running clearances.

The first seems reasonable, although it might be more accurate to say, I would prefer the words "as well as" in the place of "rather." The second point is excellent. The third would be more expressive in the form: "The consequent danger of operating with insufficient running clearances when smooth finishes are used." Experience indicates that smooth finishes will not wear away during initial break-in to the extent that rougher surfaces do, and hence, if they are initially set too tight to allow for such wear, difficulty is encountered.

The author states that a recognition of these principles should change our viewpoint as to the engineering ideal in surface finishes. The previous ideals are not stated, but it seems that good engineering has always had for its ideal the best surfaces for the job, geometry so the advantages of the surfaces could be realized, and clearances suitable for the job, all of which are the points just listed.

In conclusion, it seems to me that industry needs actual data on the relation of surface smoothness (size and shape of irregularities), geometric precision, waviness, and the suitability of the surface for its intended purpose. After all, there is no need to theorize about the matter. The means of measurement have been available for several years, and it only remains to conduct the tests.

ERNEST J. ABBOTT.[10]

Early Wind-Tunnel Studies for the Railroads

TO THE EDITOR:

I read with much interest an article by L. K. Sillcox in the June issue of MECHANICAL ENGINEERING that, among other things, treated of the streamlining of passenger equipment. I also read the editorial entitled "Aerodynamics in Transportation." The editorial appears to give all credit for wind-tunnel technique to the aerodynamic industry. This industry does deserve a great deal of credit for advancing wind-tunnel technique and for the large amount of able work done. This experimental work has added materially to our understanding of air currents and how to deal with them.

However true this may be I regretted to note that one could infer from the editorial that the railroad industry had never made any wind-tunnel tests or given any serious attention to streamlining until after the aeronautical and other industries had done something in these fields. This is incorrect, for in April, 1896, Dr. W. F. M. Goss, who was at one time president of The American Society of Mechanical Engineers, presented a paper before the Western Railway Club in which he gave an account of his experiments to determine the atmospheric resistance to the motion of railway trains. These experiments were conducted with scale models of railway cars in what would now be called a wind tunnel. In reporting upon the results of this investigation, Dr. Goss set forth certain basic principles to govern the design of railway passenger equipment in order to minimize atmospheric resistance.

I have been informed by one of the leading authorities in present-day aeronautics that the principles Dr. Goss laid down in 1896 are true today and are sustained by the results obtained from the use of more scientific instruments than were available to Dr. Goss in the early 90's. It seems perfectly clear, therefore, that Dr. Goss originally formulated the principles governing the streamlining of airplanes and automobiles, as well as railway equipment.

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[10] Physicists Research Company, Ann Arbor, Mich.

As a result of Dr. Goss's work a good deal of consideration was given by the railroad industry to streamlining in the early 90's. As pointed out by Mr. Sillcox, the Baltimore and Ohio Railroad Company made exhaustive tests with a streamlined train in August, 1900. This train was known as the "Adams Windsplitter," and speeds as high as 85 mph were made in the tests. The results of these tests did not disclose sufficient economy to justify additional expenditure to obtain streamlined effects.

Of course, it is well known today that no material saving is realized from streamlining until the speed approaches 60 mph and that appreciable saving does not obtain until speeds of 80 mph or more for appreciable distances prevail. Since airplanes operate for great distances and considerable periods of time at speeds in excess of this, streamlining is far more important in that case than either with respect to passenger trains or automobiles.

As a matter of fact, streamlining is a present-day fad and it is being applied even to stationary objects where no possible realization so far as economy of operation is concerned can be realized. I am not necessarily opposed to this practice because it has value from a styling point of view, but I do not think we need be swept off our feet by a lot of false claims that are now being made for streamlining.

The railroads utilized all the advantages of streamlining at high speeds after the public became speed-minded and therefore, would stand for high speeds with safety. Some 25 to 30 years ago the public would not have favorably responded to train speeds of 100 mph or thereabouts. It would have felt that such a speed was unsafe. In fact, in 1905, a special train on one of the important railroads of this country in making up lost time attained a speed of 127 mph. This performance was not blazed across front pages at the time because it would have frightened the public if it had known that a train had traveled so fast. Therefore, the railroad industry did not resort to streamlining in the past largely due to the attitude of the public and not in any sense to the fact that the railroad industry did not appreciate and understand the results that might be obtained from streamlining.

It is gratifying that during recent years there has been an interchange of ideas and cooperation between the aeronautic and railroad industries concerning the subject of streamlining. Such lines of cooperation are of value to both industries. It is to be hoped that cooperation and exchange of ideas, may be extended materially among all industries.

L. W. WALLACE.[11]

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[11] Director, Equipment Research Division, Association of American Railroads, Chicago, Ill. Mem. A.S.M.E.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of June 26, 1936, and approved by the Council.

CASE No. 829

(*Special Rule*)

Inquiry: Where the provisions of the Power Boiler Code or interpretations thereof require that the fusion welding of pressure parts other than the drum joints comply with the requirements of Pars. P-101 to P-110, are sample test plates required for each such weld, or if not, what are the required qualification tests for the welding operators?

Reply: It is the opinion of the Committee that it is not the intent of the Code that individual test plates be made of the joints for work of the nature outlined in the inquiry, but that the welding operators must each have demonstrated their ability to make satisfactory welds by having previously made test plates which meet all the requirements of Case No. 751 and of Pars. P-101 to P-110, including stress relieving and radiographic examination of the weld. The thickness of the qualification test plates shall not be less than the approximate thickness of the plate or parts to be welded.

CASE No. 830

(*Special Rule*)

Inquiry: Is it permissible, under the A.S.M.E. Power Boiler Code, to attach an internal cylindrical furnace not exceeding 18 in. in diameter, to the flat heads of a boiler not exceeding 36 in. in diameter by 10 ft in length, by fusion welding after flaring the ends of the furnace; providing the distance between the edges of the tubes to the cylindrical furnace does not exceed 2 in., the head outside the tube bank is stayed in accordance with the Code requirements, the welding is equivalent to that required under the rules in Pars. P-101 to P-110 omitting radiographing, and the welding is stress relieved?

Reply: It is the opinion of the Committee that the construction outlined in the inquiry, under the limitations stated, meets the intent of the Code requirements.

Economics and Technology

(*Continued from page 591*)

ing to the concentration of wealth and of monopoly and to systems of compulsion, such as nationalism and socialism. The aim and the purpose of technological progress in the future should be qualitative, and in the direction of capital saving. Only by these changes can we restore the system of freedom upon which further progress depends. The author, however, has very little to say about how this momentous reorientation of technological development is to be achieved. He mentions the trend away from giant concerns which is now observable in some industries. He hints at a final revolt against the bureaucratic régime of coercion into which we are now drifting. But his chief hope seems to lie in the possibility of changing the mental attitude and the style and standard of our cultural life. "Moral influences must be allowed to prevail in deciding the fate and in shaping the form of our civilization and man's place in it."

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

The Professional Engineer

THE PROFESSIONAL ENGINEER, by Esther Lucile Brown. Russell Sage Foundation, New York, N. Y., 1936. Boards, $5^{1}/_{4} \times 7^{3}/_{4}$ in., 86 pp., 9 tables, 1 diagram, $0.75.

THIS useful and excellent monograph is one of a proposed series dealing with the present status of certain professions in the United States. It carries evidence of having been prepared with intelligent care and thoughtful study of the recognized sources of information and statistics covering the engineering profession. For vocation counselors, teachers, parents of young men about to choose a career, and for these young men and for engineers themselves, it provides in small compass many of the essential points covered by such well-known documents as the numerous reports on the investigations of engineering education and on schools for teachers of engineering of the Society for the Promotion of Engineering Education, including the writings of Scott, Wickenden, and Hammond; the study of the 1930 earnings of mechanical engineers, made by The American Society of Mechanical Engineers; salary reports of the American Society of Civil Engineers; and publications dealing with the organization and purposes of the engineering societies, the S.P.E.E., the National Council of State Boards of Engineering Examiners, and the Engineers' Council for Professional Development.

In scope the monograph is concerned with engineering education, national engineering associations, number of engineers and demand for their services, salaries of engineers, and a concluding statement dealing with trends in engineering. Aside from brief definitions of the major branches of engineering, no attempt is made to describe the work of the engineer, or, except incidently, his functions in performing that work. It thus becomes an admirable companion to the Engineering Foundation's pamphlet "Engineering—A Career, a Culture," which it frequently mentions. The broad, clear picture it presents of the education and association activities of the engineer will be found helpful, even to engineers who imagine themselves familiar with these subjects. The treatment is sober, unbiased, and appreciative.

Obviously, the monograph is too restricted to include all of the subjects that might be discussed under its title. Some of the omissions, however, are to be regretted, even if their inclusion, or a fuller discussion where they have been mentioned, might have expanded the size and even the purpose of the work.

To the present reviewer it is a matter of regret that licensing and registration are not more comprehensively treated; that no mention seems to have been made of the work done by the engineering societies in student-branch activities, or of the grade of student member which most of them recognize in one way or another; of cooperative courses in which industries and individual plants are so helpful a factor; of education on the graduate level in institutions like Harvard University; and of the codes of ethics adopted by several societies and the procedures of internal discipline they entail.

This reviewer would also like to have found a clearer realization of the distinction which exists between the medical profession, so often quoted by those concerned with "solidarity," so-called, and the engineering profession, with more emphasis on the usual transitions of function within the profession which the average engineer usually experiences. In the discussions of earnings it would not have been out of place to have called attention to the nonfinancial compensations of teaching and government service with mention of pensions and the civil service. Comments on the "hired-man" status of the engineer would have afforded an illuminating contrast to the influences engineers, it is hoped, may exert in social and economic progress and "planning." It is also a matter of regret, through no fault of the author, that two recent studies (one is mentioned) were not completed in time to have been included—the survey by the United States Bureau of Labor Statistics, and the study of the A.S.M.E. member's job. In reference to functions, Dean Hoover's recent articles would have been a helpful addition.

It is no criticism of the monograph to list a few of the subjects touched on that afford grounds for controversy, even in the engineering profession, as, for example, research in educational institutions, professional practice by engineering educators, graduate study, the five-year course, the "liberal" curriculum, engineer graduates in production, conditions affecting supply and demand for services, and competition in consulting practice that exists among individual consultants, engineering firms, and engineering educators. And, of course, estimates of the possibilities of growth in demand for services in the engineering and the "non-engineered" industries and expressions of optimism or pessimism regarding opportunities fall into the category of controversial subjects.

But no mention of omissions or controversial matters can detract from the solid value of the monograph. It is a most welcome addition to a useful literature, and its author should be sincerely congratulated.—G. A. S.

Books Received in Library

ADVERTISING AND SELLING INDUSTRIAL GOODS. By V. D. Reed. Ronald Press Co., New York, 1936. Cloth, 6 × 9 in., 287 pp., illus., diagrams, charts, tables, $3.50. The author presents methods and workable plans which have been used in solving the advertising and sales problems of a wide range of business concerns, as a guide to executives in developing plans for their own products. Attention is given to such matters as individuality of product, market analysis, advertising agencies, catalogs, mail advertising, etc. The book is meant especially to aid small companies to make the most effective use of limited appropriations.

AERONAUTICS, Handbook of the Collections Illustrating Aeronautics—III. The PROPULSION OF AIRCRAFT, by M. J. B. Davy and G. T. Richards. His Majesty's Stationery Office, London, 1936. Paper, 6 × 10 in., 103 pp., illus., charts, tables, 2s (obtainable from British Library of Information, New York, $0.65). This publication is intended to serve as an introduction to the study of the history and development of the aircraft engine and the airscrew, with special reference to the illustrative material on exhibition in the Science Museum, London. Historical and technical surveys are provided, which are interesting brief reviews of progress. The book also includes a descriptive catalog of the exhibits in the museum and a list of important books and periodicals.

Aircraft Year Book for 1936. Edited by H. Mingos. Aeronautical Chamber of Commerce, New York. Cloth, 6 × 9 in., 526 pp., illus., diagrams, charts, tables, $3.50. This annual affords a comprehensive review of developments in American aviation, civil and military. Advances in various fields, statistics, records, and other data are given. Drawings of the principal American aircraft and aircraft engines are included.

A.T.M.—Archiv für technisches Messen. Lieferungen 50–58. R. Oldenbourg, Munich and Berlin, August, 1935–April, 1936. Paper, 8 × 12 in., illus., diagrams, charts, tables, 1.50 rm. each. This publication continues to provide an excellent survey of information upon engineering measurements and new instruments. The articles are concise, yet adequate and are by authorities. The material is classified for arrangement in looseleaf binders.

Deutsches Museum, Abhandlungen und Berichte. Jg. 7, Heft 5. Kunstseide und Zellwolle, by O. Faust. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 132 pp., illus., charts, tables, 0.90 rm. A popular, brief account of the various processes of manufacture.

Die-Casting. By C. O. Herb. Industrial Press, New York, 1936. Cloth, 6 × 9 in., 300 pp., illus., diagrams, charts, tables, $3. This manual of die-casting is a practical review of current methods and equipment. The applications of the process, the machines used, and the casting of various metals are considered. Special attention is given to die steels and die design. The book is illustrated with many drawings of dies.

Diesel Electric Plants. By E. J. Kates. American Technical Society, Chicago, 1936. Cloth, 6 × 9 in., 181 pp., illus., diagrams, charts, tables, $2. A brief, practical, nonmathematical presentation of the characteristics of the Diesel engine and the principles of Diesel-driven electric generators. Voltage regulation, parallel operation, governing, automatic operation, and other topics are considered. A chapter is devoted to Diesel locomotives.

Elementary Mechanism. By P. K. Slaymaker. D. Van Nostrand Co., New York, 1936. Cloth, 6 × 9 in., 181 pp., illus., diagrams, charts, tables, $2.25. This textbook is intended for students in engineering colleges and is based upon long teaching experience. It makes no claim to be exhaustive, but rather endeavors to discuss fundamental principles with their applications, developing the subject from elementary concepts and analyzing the material in a logical order. Special attention is given to motion transmission by linkage and to acceleration.

Elements of Practical Aerodynamics. By B. Jones. John Wiley & Sons Inc., New York, 1936. Cloth, 6 × 9 in., 398 pp., illus., diagrams, charts, tables, $3.75. This volume provides a simple exposition of the fundamentals of the subject, intended for classroom use rather than for practicing engineers. The subject is presented without calling for advanced mathematics. Modern design formulas are interpreted, and numerous practical problems provided.

Engineering Valuation. By A. Marston and T. R. Agg. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 9 in., 655 pp., charts, tables, $6. The basic principles underlying the valuation of industrial properties are set forth in this book, and their application illustrated by specific examples. A synopsis of all the controlling decisions of the United States Supreme Court which affect the practice of valuation is included, and a new principle of depreciation is developed. Numerous tables are included. The book is an admirable treatise, comprehensive and up to date, which will fill the needs of many engineers.

Experimentelle Grundlagen der Wellenmechanik. (Wissenschaftliche Forschungsberichte Naturwissenschaftliche Reihe, Bd. 38.) By S. Flügge and A. Krebs. Theodor Steinkopff, Dresden and Leipzig, 1936. Cloth and paper, 6 × 9 in., 236 pp., illus., diagrams, charts, tables; bound, 9 rm; paper, 8 rm. This book aims to provide the theoretical physicist with an account of the principles that form the basis of the theory, and the experimental physicist with the essential knowledge of the latter. The volume reviews in a connected, critical account, the experimental data scattered through the literature of the last decade, and affords a rounded survey of the present state of investigation.

Graphic Methods for Presenting Business Statistics. By J. R. Riggleman, with introduction by M. C. Rorty. Second edition. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 9 in., 259 pp., illus., diagrams, charts, tables, $2.50. This is a practical guide to the making of business charts which gives definite instructions in a clear, simple manner. The construction of the common forms of statistical charts is explained, the merits of specific types and forms are described and their possibilities and limitations set forth. This edition has been entirely rewritten.

An Introduction to the Theory of Elasticity for Engineers and Physicists. By R. V. Southwell. Oxford University Press, New York, 1936. Cloth, 7 × 10 in., 509 pp., illus., diagrams, $10. It was the purpose of the author to bridge the gap between "elementary" texts and the authoritative but difficult books of Love and Rayleigh. The bridge is necessary, because more and more physicists and engineers are being forced into advanced study of the theory of elasticity by contemporary developments in engineering. This "introduction"—it goes far into the field—should be especially useful because of the familiarity of its notation, its wealth of practical problems and examples, and its high ratio of text to equations. There is an extensive bibliography and an adequate index.

Introduction to the Theory of Linear Differential Equations. By E. G. C. Poole. Clarendon Press, Oxford, England; Oxford University Press, New York, 1936. Cloth, 6 × 10 in., 202 pp., diagrams, charts, tables, $6. This treatise, based on lectures to senior undergraduates at Oxford, is designed for students who have had an elementary course in differential equations, but have not yet specialized in one of the more advanced branches. It is not a compendium of the subject, but a selection of investigations of moderate length and difficulty which illustrate certain aspects of it. The first five chapters deal with properties common to wide classes of equations. The last five examine, in more detail, Laplace's linear equation, Lamés' and Mathieu's equations, the hypergeometric function and conformal representation. A chapter is devoted to equations with constant coefficients.

Konstruktive Lagerfragen. Grundlagen und Richtlinien für die Gestaltung von Gleitlagern. Ergebnisse einer Gemeinschaftsarbeit innerhalb der "Gruppe Konstruktion" in der ADB im Verein deutscher Ingenieure. Edited by A. Erkens. V.D.I. Verlag, Berlin, 1936. Paper, 9 × 12 in., 46 pp., diagrams, tables, 8 rm. This pamphlet presents standards for the design and construction of machine bearings, devised with the intention of using native raw materials to the greatest possible extent. Part one gives such general principles as the arrangement and construction of the bearing, behavior under load, lubrication, materials, etc. Part two gives examples of bearings for various purposes. Part three gives specifications for renewing and repairing.

Leitfaden für das Arbeitsstudium. Seelische und körperliche Voraussetzungen der menschlichen Betriebsarbeit. By E. Bramesfeld and O. Graf. V.D.I. Verlag, Berlin, 1936. Paper, 6 × 8 in., 60 pp., charts, tables, diagrams, 2.25 rm. This booklet contains two brief essays; one on the "Practical Psychology of the Time Study and Task Setting," by E. Bramesfeld, and one on "Work Physiology for the Operator," by O. Graf. The essays are intended as an introduction to the subject.

Living-Together in a Power Age. By S. S. Wyer. Association Press, New York, 1936. Cloth, 6 × 10 in., 231 pp., diagrams, charts, tables, $2.50. The author of this volume is a well-known student of the economic aspects of fuel, power, and transportation. In the present book he discusses the economic confusion of today, attempts to point out its causes, and offers a plan for economic recovery without abandonment of the capitalistic system.

Men of Science. By J. G. Crowther. W. W. Norton & Co., New York, 1936. Cloth, 6 × 9 in., 332 pp., illus., diagrams, $3.50. The book contains interesting biographies of a group of English physicists, Davy, Faraday, Joule, Thomson, and Maxwell, who lived in England in the same century and contributed vastly to scientific advance. In addition to presenting their scientific achievements, their relation to the social and intellectual life of the times is examined, and the effects of social and industrial forces upon their work are considered.

Metal Castings. By H. L. Campbell. John Wiley & Sons, Inc., New York, 1936. Cloth, 6 × 9 in., 318 pp., illus., diagrams, charts, tables, $3. This textbook presents a general course on the materials and processes used in producing metal castings. Materials, molding practice, melting equipment, the properties of the metals and the design of castings are considered. Both ferrous and non-ferrous metals are included.

Mitteilungen aus den Forschungsanstalten. Bd. 4, Heft 5, April, 1936. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., pp. 109–132, illus., diagrams, charts, tables, 2.70 rm. This number contains papers on the present development of railway motor cars, scrap smelting in the blast furnace, a new damping spring coupling, and the graphic determination of moments of inertia of rotating bodies.

Mitteilungen aus den Forschungsanstalten GHH-Konzern. Bd. 4, Heft 6, May, 1936. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 2.70 rm. The first paper in this issue, "On the Capillary Behavior of Coals," by P. Nashan, describes a method of investigation and the conclusions reached. In a second paper, "How Great Is the Loss in the Efficiency of Automobile Engines When Changed Over to Gas," by G. Rothmann, describes a method which predicts results with practical sufficiency. "An Investigation of the Influence of Additions of Cadmium upon the Resistance to Vibration of Copper Wire," by W. Engelhardt, shows that cadmium increases resistance. The final paper, by Dr. F. Lilge, is a report on "The Corby (England) Basic Bessemer Steelworks," erected in 1934.

Moderne Stahlgiesserei für Unterricht und Praxis. By B. Osann. Julius Springer, Berlin, 1936. Leather, 7 × 10 in., 261 pp., illus., diagrams, charts, tables, 26.70 rm (25 per cent reduction in U. S. A.). In this volume, Dr. Osann attempts to meet the needs of both the student and the practical foundryman. The volume opens with a comprehensive account of the various processes; crucible, open-hearth, small converter, arc and induction furnace. In each case, furnace construction, the chemical phenomena, and operation are described and illustrated by numerous examples. The properties of castings of carbon steel and alloy steels are discussed in some detail. A final section is devoted to casting.

National Physical Laboratory, Report for the Year 1935. Department of Scientific and Industrial Research, 1936. His Majesty's Stationery Office, London. Paper, 8 × 11 in., 249 pp., illus., diagrams, charts, tables, 12s. (Obtainable from British Library of Information, New York, $3.25.) This report contains a concise review of the investigations in the fields of physics, electricity, metrology, engineering, metallurgy, aerodynamics and hydrodynamics, which were carried on by the laboratory during 1935. The chief results are stated, and a bibliography of publications by the institution and the members of its staff is included.

Organization and Management of a Business Enterprise. By K. D. Fernstrom, R. F. Elder, W. P. Fiske, A. A. Schaefer, and B. A. Thresher. Harper & Brothers, New York and London, 1935. Cloth, 6 × 9 in., 703 pp., illus., diagrams, charts, tables, $4.25. This book is intended as an introductory course in business management, which will give a comprehensive view of the nature and problems of business management with special reference to their interrelationships. It should also be useful to those engaged in business who wish a concise exposition of the subject. The material is arranged in the order in which the problems of a business usually arise. Primary consideration is given to the management of manufacturing enterprises.

Petroleum Register, 1936. Seventeenth annual edition. Petroleum Register Corp., New York. Leather, 9 × 12 in., 844 pp., illus., maps, tables, $10. A thorough and comprehensive directory of the industry. Among its features are a guide to the manufacturers of equipment, lists of refiners, producers, marketers, refineries, tank steamships, grease manufacturers, natural-gasoline manufacturers, pipe lines, etc. An extensive collection of statistics and a directory of company officials are useful features. Sketch maps of the producing states and countries are provided, and a list of trade names. This edition has been revised and enlarged.

Pioneer Southern Railroad from New Orleans to Cairo. By T. D. Clark. University of North Carolina Press, Chapel Hill, N. C., 1936. Cloth, 6 × 9 in., 171 pp., diagrams, $2. This is a history of the beginnings of railroad building in Louisiana and Mississippi, and of the construction of the roads which eventually became the southern division of the Illinois Central system. The difficulties of financing and building these roads are depicted thoroughly in an interesting contribution to railroad history.

Raumheizung (Rechentafeln für Wärmetechniker); 40 Rechentafeln mit dreisprachigen Erläuterungen in Deutsch, Englisch, Französisch. By W. Goldstern. R. Oldenbourg, Munich and Berlin, 1936. Paper, 6 × 8 in., 40 pp., charts, tables, 6 rm. A colleclection of forty nomograms for the designer of heating systems, covering the calculation of heat requirements, boilers and chimneys, piping and insulation, the design of the pipe system and radiating surface, etc. The explanations of use are given in English, French, and German.

Steam Locomotive Design: Data and Formulae. By E. A. Phillipson. Locomotive Publishing Co., London, 1936. Leather, 6 × 9 in., 444 pp., illus., diagrams, charts, tables, 30s ($7.50). The aim of this book is to provide a reference book on design for those who are professionally concerned with locomotive construction, operation, and maintenance, and a textbook for designers and advanced students, which is based upon recent research and current practice. The book is based upon British practice and the plates present British designs, but the results of American research work have been used extensively in the text. The volume is a welcome addition to the scanty literature on this subject.

Symposium on Industrial Fuels. American Society for Testing Materials, Philadelphia, 1936. Paper, 6 × 9 in., 70 pp., diagrams, charts, tables, $0.75. These papers were presented at a meeting sponsored by the Engineers' Club of Philadelphia and the District committee of the American Society of Testing Materials, held in January, 1936. Coal and coke, industrial fuel oils, manufactured gas and liquefied and petroleum gas were discussed. The magnitude of each industry, availability of raw materials, and the economics of the industry were emphasized.

Symposium on Pearlitic Malleable Cast Iron. American Society for Testing Materials, Philadelphia, 1936. Paper, 6 × 9 in., 32 pp., illus., diagrams, tables, $0.60 (ten copies or more, $0.45 each). The materials here considered are those that are cast as white cast-iron and then heat-treated so that they retain significant amounts of combined carbon. Material assembled from various sources and contributions by interested individuals are presented in the symposium, which discusses the physical properties, treatment, uses, and patents.

Technical Drawing. By F. E. Giesecke, A. Mitchell, and H. G. Spencer. The Macmillan Co., New York, 1936. Cloth, 6 × 10 in., 564 pp., illus., diagrams, charts, tables, $3. This book is an excellent comprehensive treatment of the science of technical drawing. The material is arranged logically and many practical problems are given. There is a bibliography. The book is intended as a class text and reference book.

Thermodynamics for Engineers. By the late J. A. Ewing. Second edition. University Press, Cambridge, England; The Macmillan Co., New York, 1936. Cloth, 6 × 9 in., 389 pp., diagrams, charts, tables, $6. This revision of Sir Alfred Ewing's well-known textbook was practically completed before his death in 1935, and has been put through the press by A. Egerton, of Oxford University. The work has been thoroughly revised throughout.

Treatise on Screws and Worm Gear, Their Mills and Hobs. By P. Cormac. Chapman & Hall, London, 1936. Paper, 6 × 9 in., 138 pp., diagrams, 21s. This work treats of screw and worm threads from the point of view of their production, measurement, and performance. The introductory chapters give the general properties of motion with emphasis on screw motion, the envelopes of surfaces having screw motion, and the geometry of the helicoid. The theory is then applied to the solution of problems on the standard forms of screw and worm threads, and the tool forms for producing them are examined.

Die Warmwasserheizung, Anordnung und Ausführung mit vereinfachter Rohrnetzberechnung. By M. Wierz. R. Oldenbourg, Munich and Berlin, 1936. Paper, 7 × 10 in., 130 pp., illus., diagrams, charts, tables, 6.60 rm. A practical manual on the design and installation of hot-water heating systems which gives special attention to the layout of the piping. A collection of tables for the designer is appended.

Die Werkzeugmaschinen, Grundlagen, Berechnung und Konstruktion. By G. Schlesinger. Two volumes. Julius Springer, Berlin, 1936. Leather, 8 × 11 in., 818 pp., illus., diagrams, charts, tables, 147 rm. (25 per cent reduction in U. S. A.) This treatise on machine tools should be of great interest to every designer and manufacturer, because of its comprehensiveness and thoroughness, and because it makes available, in systematic fashion, the results of much modern research work. The first volume contains the text, discussing the theoretical fundamentals, the production of motion, the structural principles and typical designs for the various tools. The second volume contains fifty-two plates of machine tools manufactured by prominent German firms. These drawings, as well as the illustrations in the text, are exceedingly well reproduced.

Wire-Drawing and the Cold Working of Steel. By A. T. Adam. Second edition. H. F. & G. Witherby, London, 1936. Cloth, 7 × 10 in., 160 pp., illus., diagrams, charts, tables, 35s. This book attempts to explain the real nature of wire and other cold-worked products, to describe their physical properties, and to show how these depend on the treatment the material has received. It is intended for engineers, metallurgists, and those generally who are more interested in the product than the process of manufacture. In describing the manufacturing operations, points that affect quality are emphasized, rather than those of commercial interest. This edition has been extensively revised. The chapter on cold-rolled strip has been deleted and one on typical applications of wire added.

WHAT'S GOING ON

Including News of A.S.M.E. Affairs

This Month's Authors

ALL of the technical papers in this month's issue relate to steam power plants, and all but one have been contributed by the Power Division of The American Society of Mechanical Engineers for presentation at its Niagara Falls Meeting, Sept. 17–19. The fifth paper was presented at a meeting of the Cincinnati Section of the A.S.M.E. in May. As a description of a power plant of the superposed type, so extensively discussed in three of the other papers, its inclusion with them is timely.

A. G. **Christie**, professor of mechanical engineering, the Johns Hopkins University, member A.S.M.E., is well known to readers of **Mechanical Engineering** for his many papers on steam power plants and steam turbines, and for his acknowledged skill in preparing papers reviewing current practice. As a young man he resigned an instructorship in Cornell University to take charge of the erection and operation of the first steam turbine built by Allis-Chalmers. In 1907 he became mechanical engineer for the Western Canada Cement and Coal Company, Exshaw, Canada, but in 1909 returned to teaching, this time at the University of Wisconsin, where he remained until called to Johns Hopkins in 1914. Throughout his career Professor Christie has been closely allied with engineering through his professional practice.

E. H. **Krieg** of the engineering department of the American Gas and Electric Company, New York, N. Y., member A.S.M.E., writes on superposition practice in this country. Mr. Krieg received the degree of M.E. from Cornell University in 1922. Following graduation he became connected with the firm of Sanderson and Porter as designer, and an instructor in mathematics at Pratt Institute evening school. In 1923 Mr. Krieg became chief draftsman of the American Construction and Securities Company and later was connected with the Cuban-Dominican Sugar Co., where he had charge of the drafting room and design for the twelve sugar mills of the concern. From 1925 to 1933 he served as assistant engineer with the Electric Bond & Share Co. where he had charge of the design of five steam-electric stations and two Diesel-electric stations. Since 1933 Mr. Krieg has been connected with the American Gas and Electric Company.

Daniel Gutleben, author of the frankly written article on "Operating Experiences in a Sugar-Refinery Steam Plant" was born in Alsace-Loraine and was brought to this country as a child. His family settled in Nebraska, where he was educated, having been graduated from the University of Nebraska in 1900 with the degree of A.B. Until 1921 he was engaged in the construction of beet-sugar plants. From 1921 to 1923 he served as construction engineer at the Miami, Florida, plant of the Pennsylvania Sugar Co.; since 1923 he has been chief engineer for the concern with offices in Philadelphia, Pa.

James A. **Powell**, author of the paper on "Design Trends in 500–800 Lb Steam Plants," is vice-president and assistant chief engineer of the E. M. Gilbert Engineering Corporation, Reading Pa. Mr. Powell was graduated from North Carolina State College in 1908 with the degree of B.E. in mechanical engineering. He received the degree of M.E. in 1913 and of D.Sc. in 1931. He has been associated during his career with Westinghouse Machine Co., Pittsburgh, Pa., the Newport News Shipbuilding and Dry Dock Co., the Elliott Co., and W. S. Barstow & Co. From 1919 to 1929 he served with Barstow & Co. as mechanical engineer with complete supervision of design, materials, and engineering in the installation of turbines and boilers, and in 1930 he became assistant chief engineer and three years later was appointed to the position of vice-president. He is a member of the A.S.M.E.

D. S. **Brown**, manager of the production department of the Union Gas & Electric Company, Cincinnati, Ohio, contributes the article on "A Superposed Power Station." Mr. Brown received his degree in electrical engineering from the University of Cincinnati in 1920 and since that time has been continuously with his present concern. From 1923 to 1929 he was superintendent of production and since then has been manager with duties covering the operation and maintenance of the steam-electric power stations of the company. Mr. Brown is a member of the A.S.M.E. and of the Prime Movers Committee of the Edison Electric Institute.

The review of Ferdynand Zweig's book on "Economics and Technology" is by **Ralph** E. **Freeman**, head of the department of economics and social science, Massachusetts Institute of Technology, under whose direction monthly reviews of books on economics of interest to engineers are prepared.

Samuel M. Vauclain Celebrates Eightieth Birthday

SAMUEL M. VAUCLAIN, honorary member of The American Society of Mechanical Engineers, celebrated his eightieth birthday on May 18, 1936. On May 19 a group of his friends and associates in the Newcomen Society gathered in Philadelphia to extend greetings and congratulations.

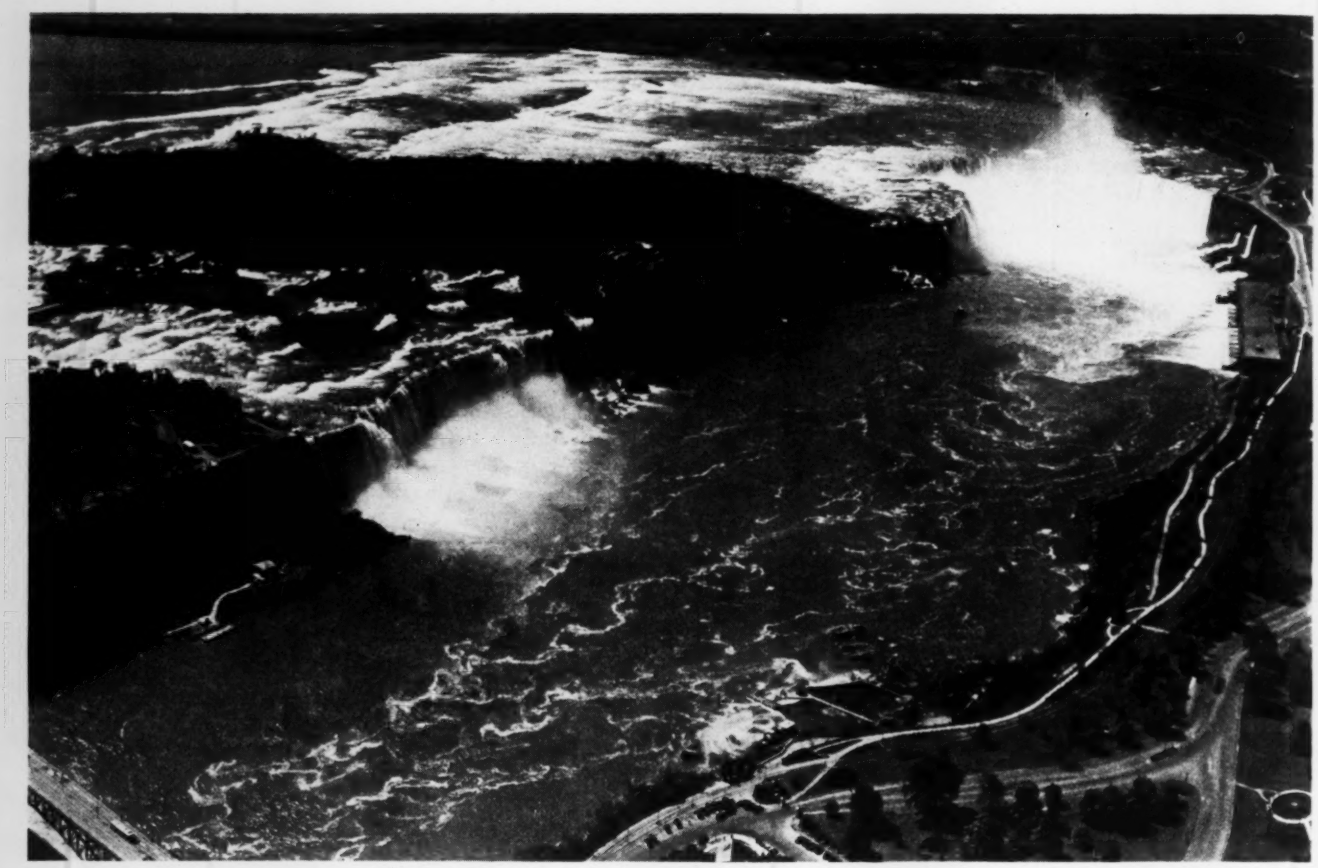
The first speaker was George B. Cortelyou, former president of the Consolidated Gas Company, New York, who, after quoting from the "Autocrat of the Breakfast Table" the passage "Set ye up a standard in the land," pointed out that Mr. Vauclain had established a standard of thoroughness in research, of fairness in study, and of honesty in ascertainment.

William C. Dickerman, president of the American Locomotive Company, paid high tribute to his principal competitor and said that he had "fought the good fight and kept the faith." At the close of his remarks he presented to Mr. Vauclain a silver cup from his friends in the Newcomen Society. The following inscription appears on the cup: "Samuel M. Vauclain, Great Engineer, Able Administrator, Good Citizen."

SILVER CUP PRESENTED TO SAMUEL M. VAUCLAIN, HONORARY MEMBER, A.S.M.E., BY MEMBERS OF THE NEWCOMEN SOCIETY

In reponse Mr. Vauclain told how he had, in his nursery days and in his first work in the Pennsylvania Railroad roundhouse, learned to deal with emergencies. He then recited three specific emergencies in his dramatic career. The first related to the success of building, operating, and getting paid for the rack locomotives for the Pikes Peak Railroad. The second dealt with securing a contract for rifles from Russia during the War and bringing home safely a set of master gages that were necessary for their manufacture. The third dealt with his relation to the administration of railroads during the War and with standard design for locomotives.

Mr. Vauclain spoke with his usual vigor and force and the occasion was a most interesting one for all present.



AIRPLANE VIEW OF NIAGARA FALLS

A.S.M.E. MEETING AT NIAGARA FALLS

Affords Opportunity to Review Current Practice and Recent Developments

NIAGARA FALLS, where such significant developments in the history of the generation, distribution, and use of electric power have been made, is an appropriate place for the meeting, September 17–19, of The American Society of Mechanical Engineers, for at Niagara Falls, on these dates many delegates to the Third World Power Conference will be stopping during the post-Conference study tours. And it is also appropriate that emphasis in the technical papers comprising the program for that meeting is to be on power development. Headquarters for the meeting will be the Hotel Niagara.

TO VISIT SCHENECTADY BEFORE THE MEETING

Arrangements have been made so that members and guests of the A.S.M.E. en route to Niagara Falls may stop off at Schenectady on Wednesday, September 16, for an inspection of the General Electric Company's plant. This special visit will be made jointly with two of the Study Tours that have been set up for delegates to the World Power Conference.

In company with the distinguished visitors from abroad, members and guests of the A.S.M.E. will spend Wednesday morning in an inspection of the vast works of the General Electric Co. The visits will include the departments engaged in the manufacture of household refrigerators, and those in which large hydroelectric generators and large motors for industrial applications are constructed.

The Schenectady plant of the New York Power and Light Corporation, which is famous for two unusual features, will be visited. This is one of the few out-of-door power stations in the United States, and also one of the few mercury-vapor plants.

After lunch the group will visit the famous General Electric Research laboratory, where more than 400 physicists, chemists, and engineers are engaged in research and development on X-rays, electron tubes for radio and power, gaseous-discharge lighting, electric insulation, the properties of metals, and many other fields of investigation. The afternoon tour will feature brief talks by some of the outstanding scientists of the laboratory on a few of the new developments which are being made. Among the subjects discussed will be magnetic materials, endurance properties under stress, and mechanical problems.

The party will leave Schenectady by train in time to spend Wednesday night at Niagara Falls.

THE TECHNICAL PROGRAM AT NIAGARA FALLS

Details of the technical program to be presented on Thursday and Friday, September 17 and 18, are given in the following outline:

SEPTEMBER 17

THURSDAY MORNING

9:30 a.m. Power

Chairman: Alex Bailey

Development and Performance of American Power Plants, by A. G. Christie

Superposition, by E. H. Krieg

Design Trends in 500–800 Lb Steam Plants, by James A. Powell

Transportation

Chairman: George W. Rink

Performance of Diesel-Electric Locomotives in the Buffalo Area, by J. C. Thirlwall

The Mechanics of the Car Retarder, by N. C. L. Brown

THURSDAY AFTERNOON

2:00 p.m. Power

Chairman: J. N. Landis

German Boiler and Turbine Practice, by Otto Schoene

Discussion of British Boiler and Turbine Practice

Operating Experiences in a Sugar-Refinery Steam Plant, by Daniel Gutleben

Engines

Chairman: R. F. Gagg

Latest Developments in Aircraft Power-Plant Accessories, by S. H. Webster

Piston-Ring Friction in High-Speed Engines, by Louis Illmer

THURSDAY EVENING

6:30 p.m. Dinner meeting

SEPTEMBER 18

FRIDAY MORNING

9:00 a.m. Power

Chairman: J. L. Yates

Operating Conditions at Huntley Station, by H. M. Cushing

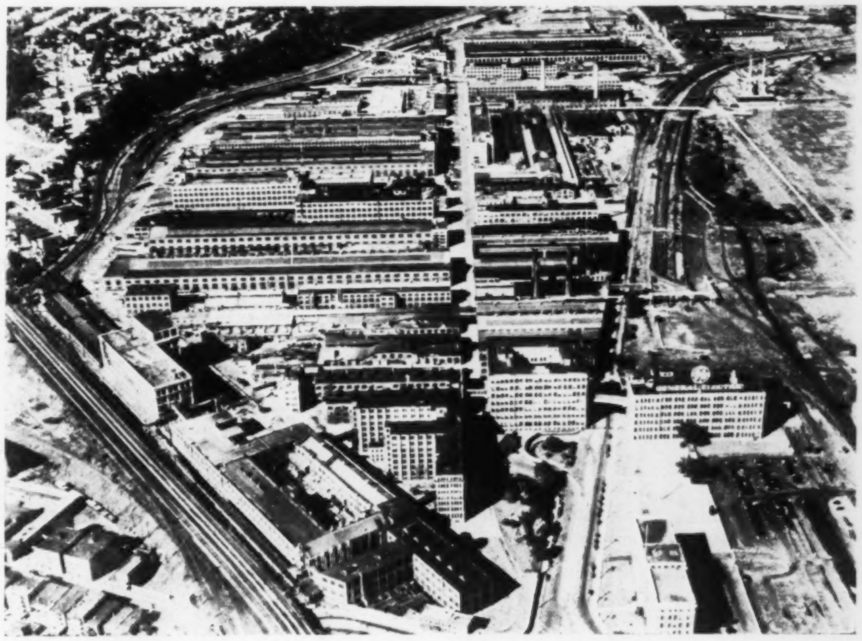
10:00 a.m. Fuels

Chairman: K. M. Irwin

Design and Operating Problems When Using Gas- and Oil-Fired Boilers for Stand-By Steam-Electric Stations, by V. F. Estcourt

German Furnace Design and Combustion, by Otto Schoene

NIAGARA GORGE FROM DEVIL'S HOLE



SCHENECTADY PLANT OF GENERAL ELECTRIC COMPANY—AIRPLANE VIEW TOWARD SOUTHWEST

Hydraulic Research

Chairman: R. W. Angus

American Hydraulic-Laboratory Practice, by Leslie J. Hooper

Hydraulic-Laboratory Projects of the Corps of Engineers, U. S. Army, by F. H. Falkner

9:30 a.m. Wood Industries

Chairman: L. N. Nichols

Discussion of Material Waste Reduction in Woodworking Plants, by F. R. Hassler

Grinding and Maintenance of Cemented Carbide Fitted Saws and Woodworking Knives, by C. M. Thompson

FRIDAY AFTERNOON

2:00 p.m. Process

Chairman: C. E. Harrington

Drum and Contact Drying, by Guy Harcourt

Drying and Pulverizing Developments

Hydraulics

Chairman: Norman Gibson

Hydroelectric Practice in the United States, by A. C. Clogher

Canadian Hydroelectric Practice, by T. H. Hogg

Woodworking

Plant-Inspection Trips to Kittinger Furniture Company and Wurlitzer Piano Company

FRIDAY EVENING

8:00 p.m. Wood Industries

Chairman: H. B. Carpenter

Factors to Be Considered in Substituting One Wood for Another, by R. P. A. Johnson

Use of Synthetic Resins in Modern Varnishes for Wood Protection, by R. J. Moore

SEPTEMBER 19

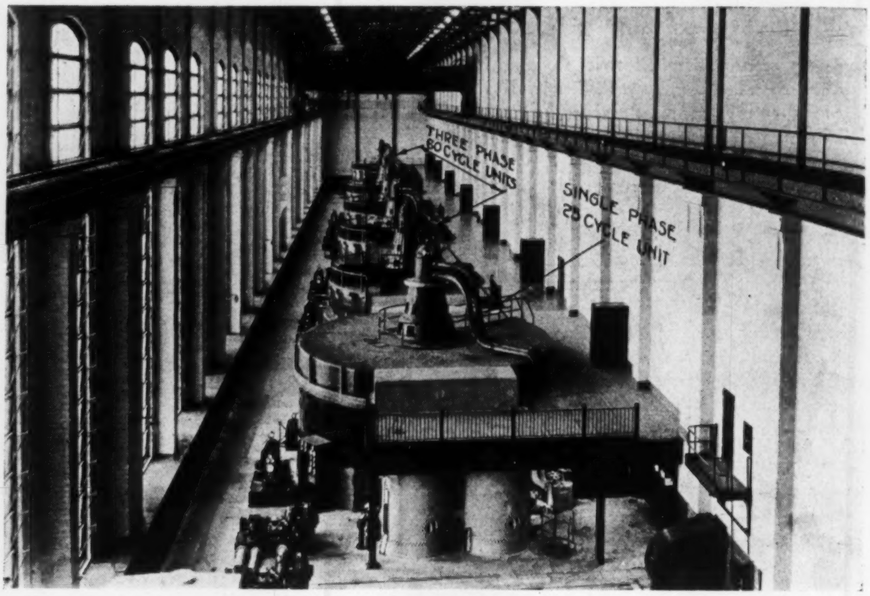
SATURDAY

Trip to Bethlehem Steel Corporation's new strip-mill plant

POWER ENGINEERS CANNOT AFFORD TO MISS NIAGARA FALLS MEETING

As will be seen from the program, emphasis is placed on current practice in power. With such papers, and with an audience including international figures in the power field, power engineers in this country can ill afford to miss the opportunity that the A.S.M.E. Niagara Falls meeting presents. The current issue of MECHANICAL ENGINEERING has been given over to four of these papers, which are published in full, dealing principally with steam power. Professor Christie's paper, with its valuable tables, is one of his characteristic and masterly reviews of current practice. Mr. Krieg confines himself to the much discussed subject of superposition, and includes statistical data on the important superposed power plants. A discussion of plants operating at pressures from 500 to 800 lb is presented by J. A. Powell. Operating men, designers, manufacturers of equipment, and engineers interested in industrial power plants will find a stimulating and frank recital of operating experiences in a sugar-refinery steam plant in the paper by Daniel Gutleben.

But these four, published in advance of the meeting, do not exhaust the list of papers that will attract the power engineer. On Friday



INTERIOR VIEW OF POWERHOUSE OF SAFE HARBOR DEVELOPMENT, SHOWING ONE 25-CYCLE AND FIVE 60-CYCLE UNITS

(From A. C. Clogher's paper on "Hydroelectric Practice in the United States.")

morning, H. M. Cushing will present a paper on operating conditions at the Huntley station of the Buffalo General Electric Company. It is expected that his paper will include references to interconnection and that the paper and the discussion it is bound to provoke will be something engineers will not wish to miss. Nor will they wish to be absent when V. F. Estcourt talks about design and operating problems when using gas- and oil-fired boilers for stand-by stations.

Current German practice in power engineering will be reported by Otto Schoene well known to engineers in this country. He will discuss boiler and turbine practice and furnace design and combustion in his country. A paper on British boiler and turbine practice will contribute another opportunity for an exchange of ideas and experiences in the truly international atmosphere that will prevail at Niagara Falls.

HYDROELECTRIC PRACTICE AND HYDRAULIC RESEARCH TO BE REVIEWED

In a group of four extensive and complete papers current practice in hydroelectric plants in this country and Canada, and in hydraulic research will be adequately reviewed. Here again the presence of eminent engineers from abroad should guarantee much discussion and exchange of experience that will be of benefit to all. These papers, sponsored by the A.S.M.E. Hydraulic Division, will be presented Friday morning and afternoon.

The papers on hydraulic research are devoted to hydraulic-laboratory practice in the United States. Leslie J. Hooper, whose paper is entitled "American Hydraulic-Laboratory Practice," describes briefly representative American hydraulic laboratories and their work in recent years. The paper lists (1) manufacturers' and government laboratories engaged in a commercial form of research, with an indication of the type of work being done; (2) college and university laboratories used for instruction, and for scientific and commercial research; (3) laboratories used for instruction and scientific research. The paper is amply illustrated; and comment is made on such subjects as water-wheel laboratories, cavitation testing, pump testing, instrument calibration, flow of water, model hydraulic structures, river laboratories, transportivity, and towing tanks.

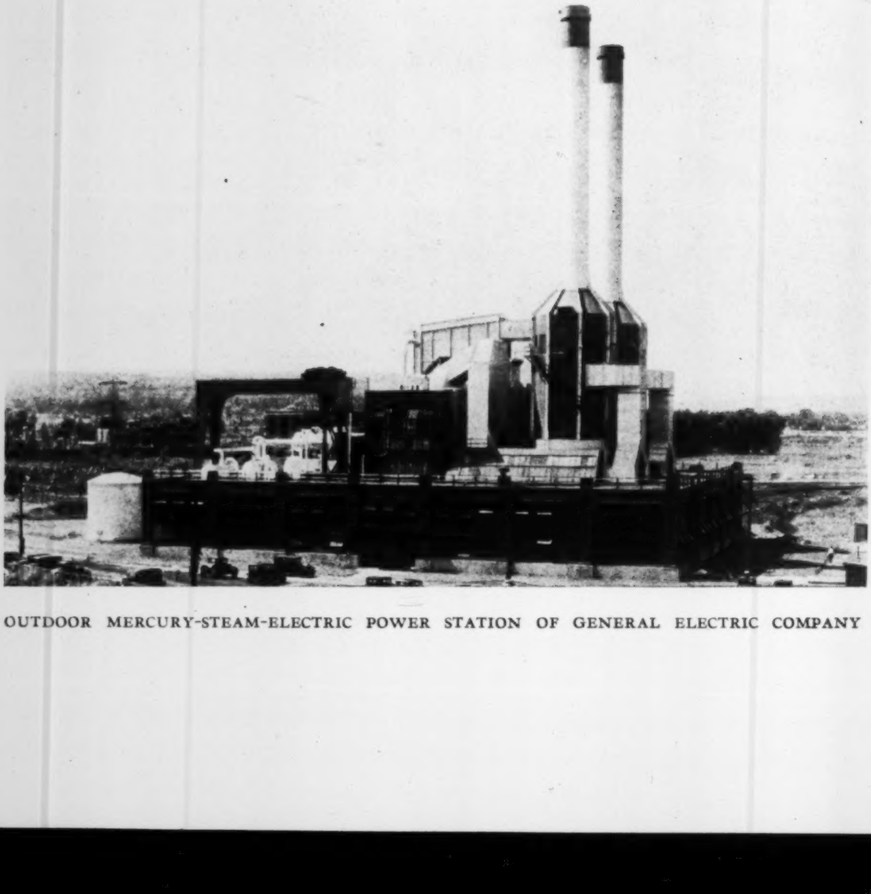
F. H. Falkner discusses hydraulic-laboratory projects of the Corps of Engineers, U. S. Army, which involve 303 separate experiments conducted by 41 division and district offices from Maine to California, all tabulated in the paper. His paper is specifically concerned with types of field problems subjected to experimental analysis, the facilities maintained for this work, and the accomplishments of the program. The illustrations are of special interest.

The two papers on hydroelectric practice are able companion pieces to those on steam-power-plant practice already mentioned. A. C. Clogher will cover plants and practice in the United States, and T. H. Hogg those in Canada. Never has there been a period of such wide popular interest or active construction in hydroelectric-power developments. Messrs. Clogher and Hogg have made a valuable contribution to engineering literature in their papers which summarize and tabulate recent practice and station design. With the presence at Niagara Falls of many eminent engineers from abroad, in this country in connection with the Third World Power Conference and the Second Congress on Large Dams, a discussion is predicted that will be unique and of world-wide interest.

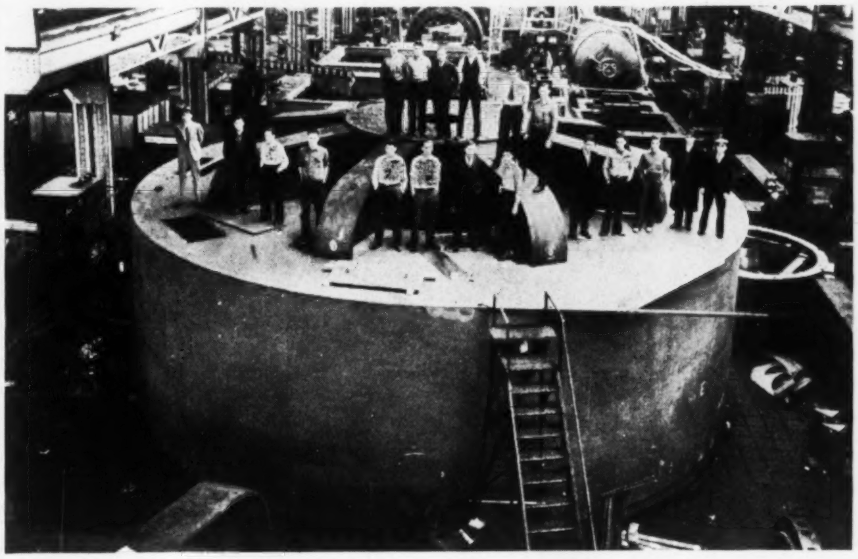
POWER NOT THE ONLY SUBJECT TO BE DISCUSSED AT NIAGARA

But power is not the only subject to be discussed at Niagara Falls, as a glance at the technical program will prove. Two papers on Thursday morning, of diverse interest not only to railroad engineers but to others will be those by J. C. Thirlwall on the performance of Diesel-electric locomotives in the Buffalo area and the mechanics of the car retarder by N. C. L. Brown. With interest in Diesel engines on the railroads at a particularly high level, a discussion of performance is especially timely. The mechanics of the car retarder should offer opportunity for practical questions and informed discussion.

Engineers interested in aeronautics will wish to attend the Thursday afternoon session at which S. H. Webster will present a paper



OUTDOOR MERCURY-STEAM-ELECTRIC POWER STATION OF GENERAL ELECTRIC COMPANY



GENERATOR FOR BOULDER DAM UNDER CONSTRUCTION AT GENERAL ELECTRIC COMPANY

on developments in aircraft power-plant accessory equipment. Mr. Webster will discuss hand or combination hand and electric inertia starters, the external energizer, the direct-cranking electric starter, generators and dynamotors, vacuum-instrument pumps, deicing-equipment accessories, hydraulic pumps for remote control, the engine synchroscope, direct- and remote-reading flow meters, supercharger regulators, automatic mixture and power control, and the auxiliary power-supply system for long-range aircraft.

Louis Illmer, in a paper on piston friction, will point out that a rise in frictional losses has accompanied the recent trend toward higher rotative speeds in automotive engines, and that the accumulative pressure built up in the annular pocket under the first piston ring has contributed to this rise. He will evaluate analytically the piston-ring friction of a heavily loaded engine running at its highest speed.

The A.S.M.E. Wood Industries Division will sponsor four papers to be delivered at two sessions, Friday morning and evening. The subjects to be discussed in the morning are material-waste reduction in woodworking plants, which will be presented by F. R. Hassler, and the grinding and maintenance of cemented carbide fitted saws and woodworking knives, by C. M. Thompson. The two papers for presentation Friday evening relate to the substitution of one wood for another, prepared by R. P. A. Johnson, and the use of synthetic resins in modern varnishes for wood protection, by R. J. Moore, which should have a wide appeal.

The Division has arranged for a special inspection of the plants of the Kittinger Furniture Company and the Wurlitzer Piano Company, for Friday afternoon.

LACKAWANNA STRIP MILL TO BE INSPECTED SATURDAY

In addition to the inspection trips already noted, arrangements have been made for an inspection, on Saturday, of the Bethlehem Steel Corporation's new strip mill at the Lackawanna plant. This modern mill has been opened only recently and is an instructive example of up-to-date steel-mill practice.

A number of other inspection trips of plants in the vicinity of Buffalo and Niagara Falls are also being planned. Among these, of special interest to power engineers, is the well-known Huntley station of the Buffalo General Electric Company.

PROGRAM BEING ARRANGED FOR THE WOMEN

As usual a special program of interest to the women is being arranged for the Niagara Falls meeting. The romantic and spectacular attraction of the Falls itself, with the many sight-seeing advantages the region affords, will be supplemented by others of a varied nature. Announcement of details cannot be made at this time.

DINNER MEETING THURSDAY EVENING

A social feature of interest to all members and guests and the women will be the dinner meeting, scheduled for Thursday evening. Dinner will be served in the ballroom of the Hotel Niagara. President Batt will be present and will be one of the speakers. Other features are being planned, but as yet no information can be made public.

The dinner promises to be unusually enjoyable because of the presence of the engineers from abroad who are taking the post-conference study tours, and because of the participation of members of the Engineering Institute of Canada who are cooperating with The American Society of Mechanical Engineers in this event.

ARRANGEMENTS FOR VISITING CANADA

We are informed by the Deputy Minister of Immigration and Colonization at Ottawa, Canada, that the regulations of his department relating to the admittance of tourists and others into the Dominion are simple and reasonable. He writes:

"Persons who are citizens of the United States and who are entering Canada as tourists may expect no inconvenience whatever. In the case of any of your delegates or their friends who are not citizens of the United States, and who wish to pay a visit to Canada, it would be well for them to be in a position to satisfy the Canadian officer at the International boundary that they are legally resident in the United States and will have no difficulty in returning to your country. Tourists' automobiles are admitted without charge and may be driven for pleasure under their state licenses in Canada for a period of sixty days, which period may be extended upon application."

BUFFALO SECTION ACTIVE IN PLANNING

Active in planning the A.S.M.E. meeting and its technical and social features is the Buffalo section of the Society, in cooperation with the various professional divisions sponsoring sessions and the Committee on Meetings and Program. In view of the importance of the subject matter under discussion at the technical sessions and the presence of numerous engineers from abroad, it is expected that attendance will be large. In a country emerging from a depression the engineering profession should be keenly alert to take stock of recent progress made in technological developments, which will be reviewed at the meeting. In the field of power particularly, the Niagara Falls meeting of the A.S.M.E. affords an extraordinary opportunity. Mechanical engineers cannot afford to miss it.

MODEL OF CAPE CODE CANAL AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

(From L. J. Hooper's paper on "American Hydraulic-Laboratory Practice.")

NIAGARA FALLS AT NIGHT

Fifty Nations to Be Represented at Third World Power Conference, Washington, D. C., Sept. 7–12

PLANS for the Third World Power Conference and the Second Congress on Large Dams, to be held at Washington, D. C., September 7–12, as announced in the May and July issues of MECHANICAL ENGINEERING, are practically complete, and a price list of papers, with a revised schedule of conference and congress sessions, has been issued.

Upward of 700 delegates from 50 nations are expected to attend the conference and congress, which are open to all engineers upon registration and payment of a fee of $10. At Washington, in addition to the sessions at which the numerous papers, not to be presented individually, will be summarized in groups on related subjects for purposes of discussion, there will be a banquet for which reservations must be made in advance, $7.50 per person, and receptions at the White House, Mount Vernon, and the Bliss Estate, free to delegates and members.

Failing to find a dining room with facilities for serving the 3000 persons expected to attend, the Washington committee has made arrangements with the railroads to convert the main waiting room of the Union Station into a banquet hall.

Presiding at the sessions will be the vice-chairman of the American National Committee, Dr. William F. Durand, past-president and honorary member of The American Society of Mechanical Engineers, whose broad knowledge of engineering and ability to speak English, French, German, and Italian make him admirably equipped to perform the functions of this office. The Society will be officially represented by its president, William L. Batt.

Under government frank, information regarding the conference and congress, a revised program, and application blanks for membership will be mailed to every member of the Society.

Comprehensive exhibits to illustrate developments in power production and utilization will be on display at Washington. Photographs, models, operating and stationary, moving pictures, and transparencies will be used. Charts will show the development of electric power production, various types of use, tendencies in regard to rates and consumption, and actual and potential power capacity. Models of electrical research laboratories will be exhibited. A few miles from Washington a completely electrified farm will be open to visitors. The American Engineering Council has been assigned space for display at the Hotel Mayflower.

In the July issue of MECHANICAL ENGINEERING appeared announcement of the study tours which are being conducted prior to and following the conference. These tours will last from five days to two weeks and have been laid out according to the major special technical interests of delegates. They will cover practically everything that can be seen in the way of power production, transmission, and use east of the Mississippi. They will be supplemented by "round table" discussions. A special post-conference tour is being planned which will include Glacier Park, the Grand Coulee, Seattle, San Francisco, and Boulder Dam.

The Niagara Falls Meeting of The American Society of Mechanical Engineers, September 17 to 19, will be held at a time when two of the post-conference tours will be passing through that locality and will provide a series of technical sessions of interest to power engineers. An announcement of this meeting and its program appears on pages 604 to 607 of this issue.

A.E.C. News From Washington

THE reorganization movement is gaining momentum with three investigating committees holding the "ax over Washington." Each committee is moving cautiously and while the President's Committee on Administrative Management is most active among government officials, no hearings are reported to be scheduled prior to November elections. In the meantime, there is much speculation regarding the seriousness of the reorganization intentions and the possibility that overlapping responsibilities may result in frustration of purpose.

Although similar studies in the past have each left their train of broken promises, false hopes for retrenchment, futile Congressional investigations, and ineffectual recommendations, the field never seemed so ripe for reorganization and economy measures. Entering many new activities, the federal government has piled 40 new agencies on top of an already top-heavy administrative structure. Civil Service reports an increase of more than 250,000 civilian employees since February, 1933. Unofficial figures show the federal payroll for June, 1936, was $326,159,486 for 4,664,732 employees. That is an obligation of about $2.65 per month against every man, woman, and child in the United States.

On the receiving end, it is estimated that 16,314,248 people have already received benefits from the emergency agencies. Emergency funds have gone into every state and territory, and Congressional appropriations for that purpose run into many billions with approximately $9,487,163,446 in a single session. The public debt at the close of the fiscal year for 1936 amounted approximately to $33,779,000 and the total revenue for the 1936 fiscal year fell about $4,764,000 short of the total expenditures.

The proportions of the task ahead of the "Reorganization Committees" are difficult to visualize but an idea may be gained from reports that duplications in service and overlapping functions between old and new bureaus have reached a point where there are as many as 23 agencies dealing seriously with a single problem. Such knowledge is said to have been in possession of Senator Byrd when he succeeded in getting the Senate resolution authorizing the investigation to read that the Senate Investigating Committee should sit, not only in the next, but in "succeeding Congresses."

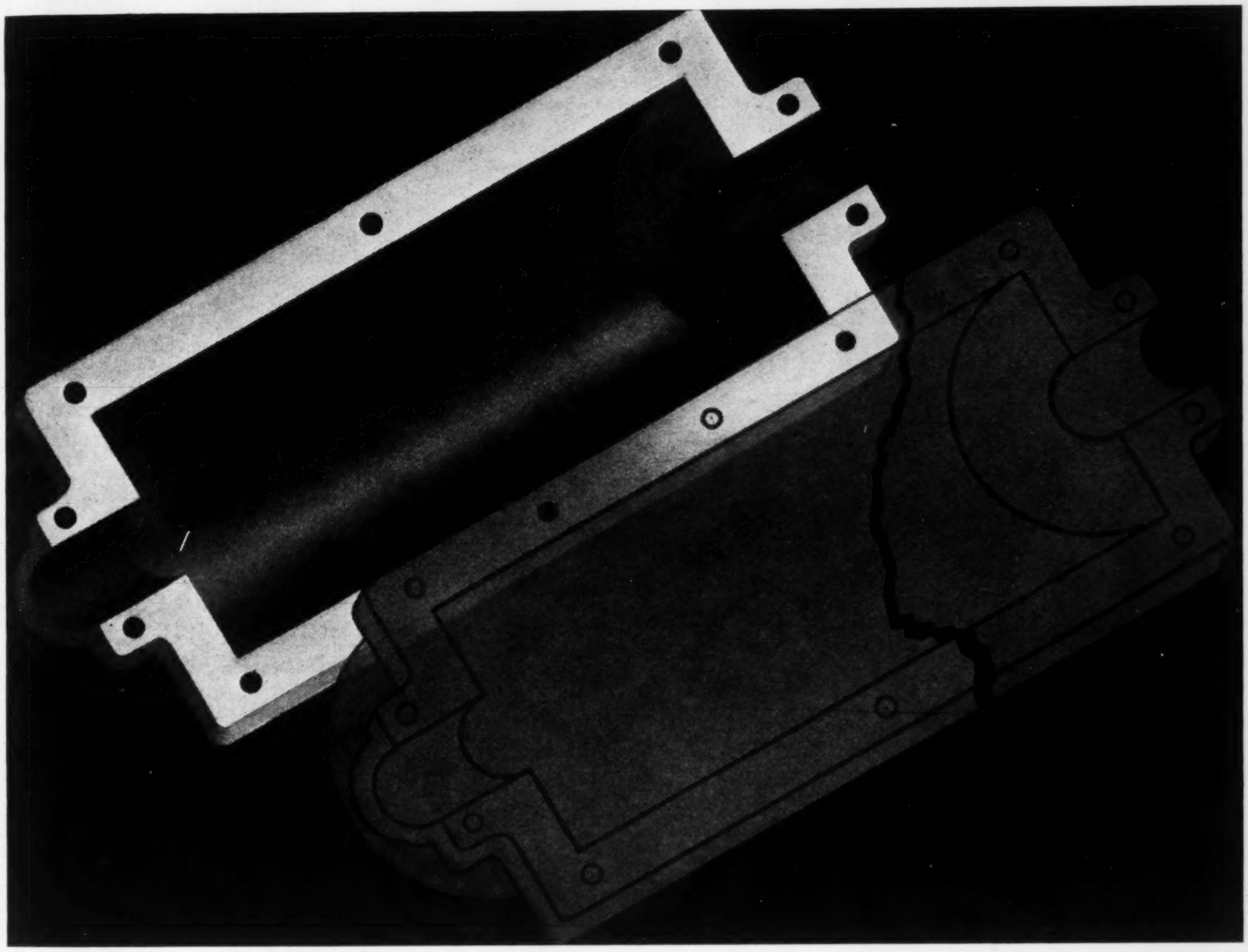
Regardless of past experience and political implication, the Byrd resolution with a continuing authority to bring administrative inefficiencies to the surface stands without handicap except for limitation of funds, until repealed by an Act of Congress.

GOVERNMENT AGENCIES' ACTIVITIES

The public-works inventory for 1936 is a joint undertaking by PWA and WPA under direction of the National Resources Committee. It will be similar to the one made a year ago but it is to include all public-works

(*Continued on page 610*)

"At last! . . . and MOLY did it!"



WHERE is the foundryman who has not encountered difficulties with malleable-iron castings due to primary graphite — especially in parts where coring prevents rapid cooling of heavy sections?

A founder of housings for a piece of apparatus subject to high-pressure loads had such a problem. Coring was complicated and sections were heavy. Rejects were 100%.

The addition of .35% Moly corrected the trouble after everything else had failed. Rejects ceased. Moly not only made production possible, but made the castings even better than had been anticipated.

Your cast-iron problems may be different. They may involve matters of increased toughness, or resistance to heat, or merely the production of high-test iron. In any case, it will pay you to investigate Moly — "industry's most versatile alloy."

Our technical book, "Molybdenum," is full of practical information. Our periodical news-sheet, "The Moly Matrix," keeps you informed as to the latest developments in Moly irons and steels. They and the help of our experimental laboratory are yours for the asking. Climax Molybdenum Company, 500 Fifth Avenue, New York City.

MOLY "Mo-lyb-den-um

CUTS COSTS

CREATES SALES

possibilities for the next six years. The field work is to be done by local government employees, of the cooperating agencies, who are to submit their estimates to the planning boards of 46 states. Project possibilities are to be classified by type, geographical location, and priority. Such inventories have not been important factors in the approval or rejection of individual projects but their continuation suggests that the Administration is not abandoning "made work" for the jobless.

The Securities and Exchange Commission released the following statements on July 31, 1936. "Analysis of statements registered under the Securities Act of 1933, during the six months ended June 30, 1936, indicates that securities with estimated gross proceeds of $2,664,947,000 became fully effective, slightly more than four times as great an amount as the $665,339,000 effectively registered during the first half of 1935. These figures are exclusive of amounts registered in connection with exchange plans for companies in reorganization or in connection with the issuance of certificates of deposit and voting trust certificates. The figures, however, include $494,378,000 in 1936 and $104,142,000 in 1935 for securities intended for purposes other than cash sale for the account of the registrants.

"Manufacturing companies were the largest registrants with a total of $1,026,291,000. Utility companies were second with $841,421,000 and financial and investment companies were next in importance with $351,842 securities.

"Fixed-interest bearing securities constituted the predominant type of security included in these registrations. About 75 per cent of the proceeds after the payment of commissions, discounts, and other expenses, was proposed to be used for repayment of indebtedness, chiefly through refunding operations."

WHO'S WHO IN ENGINEERING

At the request of the Lewis Historical Publishing Company of New York, publishers of the three earlier editions of "Who's Who in Engineering," a sponsoring committee for the fourth edition has been appointed by President Andrey A. Potter. Because of his previous service on similar committees, President Potter has been prevailed upon to act as chairman with the following members: Messrs. A. W. Berresford, D. S. Kimball, C. F. Scott, George T. Seabury, C. E. Davies, H. H. Henline, A. B. Parsons, J. F. Coleman, and F. M. Feiker.

It is anticipated that the questionnaires outlining the qualifications for inclusion in the new edition will be mailed to members of the profession early in the fall. Engineers eligible for this new edition will be listed without obligation. The new edition will be published in the Spring of 1937 and may be purchased for $10 per copy.

VOCATIONAL CLINIC FOR EMBRYO ENGINEERS

Five out of six Washington high-school graduates, picked by their respective principals, as the leaders in the graduating class of 1936, stated to a recent audience of the Rotary Club of Washington, that they expected to be engineers. One had chosen civil engineering, two mechanical, one electrical, and one management engineering. Each was an outstanding personality. They gave a better account of themselves than perhaps most of their listeners could have done. Dr. Mann, Secretary Emeritus of the American Council of Education, has suggested that the professional men in each city could well organize a "vocational clinic," and offer to young men and their parents the chance to learn the training and opportunities for each profession.

Associates Honor O. P. Hood

O. P. HOOD, chief of the technologic branch and chief engineer of the mechanical division of the United States Bureau of Mines, Department of the Interior, member, The American Society of Mechanical Engineers, retired on June 30, following 25 years of service with the Bureau. A farewell luncheon, attended by more than 100 associates and former associates of the Bureau of Mines and from technical and scientific societies, in which he has been active, was given at the Hotel Harrington, Washington, D. C., June 27. Director John W. Finch and two former directors of the Bureau, H. Foster Bain and F. G. Cottrell, and several others, made addresses. Various tokens of appreciation were presented to Dr. Hood.

A.S.M.E. Welding-Practice Symposium, Cleveland, Oct. 22–23

THE Machine-Shop Practice, the Iron and Steel, and the Applied Mechanics divisions of The American Society of Mechanical Engineers have joined in sponsoring a Welding-Practice Symposium to be held in cooperation with the American Welding Society at the Hotel Cleveland, Cleveland, Ohio, October 22 and 23, during Metal Week of the Metal Congress and Exposition.

C. W. Obert is chairman of the committee organizing the Symposium which will be given in four sessions. Papers will cover stress analysis, weldability of alloy steels, tests on welded-alloy steels, welding of heavy machinery and steel-plate construction, use of steel plates, modern resistance-welding development, weldability of nonferrous metals, inspection of welds, and principles involved in selecting casting versus welding.

The object of arranging such a symposium is to provide members of the A.S.M.E. with a series of papers in compact form on welding-practice technique and its effect on design and production. The committee has been successful in securing experts in this field to prepare these papers and it is hoped that they may be issued stimultaneously in advance of the meeting to stimulate discussion on problems and experiences in welding practice.

Other organizations holding meetings in Cleveland during Metal Week are the American Institute of Mining and Metallurgical Engineers, the American Society of Metals, the American Welding Society, and the Wire Association.

International Conference on Letter Symbols for Heat and Thermodynamics

AN ATTEMPT will be made to relieve the present chaotic situation with regard to symbols for equations in thermodynamics at an International Conference which has been called by The American Society of Mechanical Engineers, to be held in the Engineering Societies Building, 29 West 39th Street, New York, N. Y., on September 14 and 15, 1936. The Conference has been scheduled at this time so that some of the delegates to the World Power Conference to be held the previous week in Washington, may act as representatives at this Conference.

American usage in regard to such symbols has become fairly well standardized since the publication of the list prepared by the A.S.A. Subcommittee on Symbols for Heat and Thermodynamics. This is now generally adhered to in America, but other lists have been issued by various European bodies. The Conference will endeavor to compromise the differences in the several lists. While it is understood that no international body has authority to standardize any list of symbols, it is hoped nevertheless that the list finally selected by the Conference will be accepted by the various bodies represented as the best possible compromise and in this way automatically become an international standard.

Participation in the Conference has already been promised by Comité Electrotechnique Suisse, British Standards Institution, Association Francaise de Normalisation, Ausschusz für Einhaten und Formelgroszen (of Germany), Verein deutscher Ingenieure, Institution of Gas Engineers (of England), Comité Electrotechnique Francais, and negotiations are in progress with International Congress of Refrigeration, The Physical Society (of England), National Research Council of Canada, Institution of Heating and Ventilating Engineers (of England), Institution of Mechanical Engineers (of England), and Chemical Society (of England). The American interests will be represented by the A.S.A. Subcommittee on Symbols for Heat and Thermodynamics.

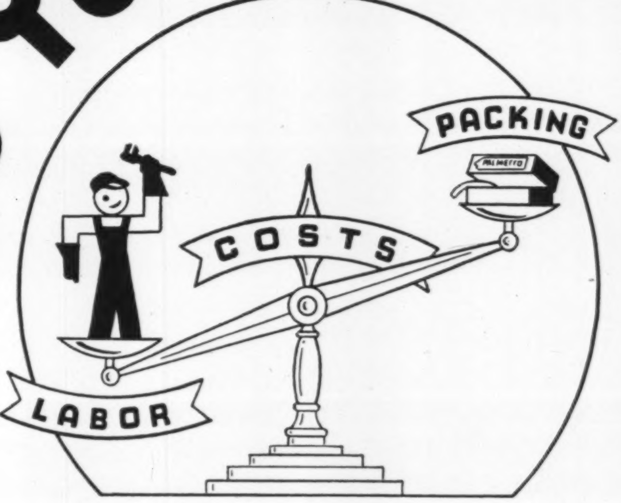
Engineering Foundation Projects

IN the report of June 30 of the Engineering Foundation the following note relates to projects for The American Society of Mechanical Engineers:

During the quarter work was continued by the committees on cottonseed processing, critical-pressure steam boilers, fluid meters, boiler feedwater, and strength of gear teeth. Manuscript for a cutting-of-metals handbook was still in process of editing. For the fiscal year 1936–1937 grants totaling $5000 were made for cutting fluids, critical-pressure steam boilers, fluid meters, strength of gear teeth, effect of temperature on properties of metals, lubrication, and speed of deformation vs. strength of metals.

(*Continued on page 612*)

DO YOU KNOW..



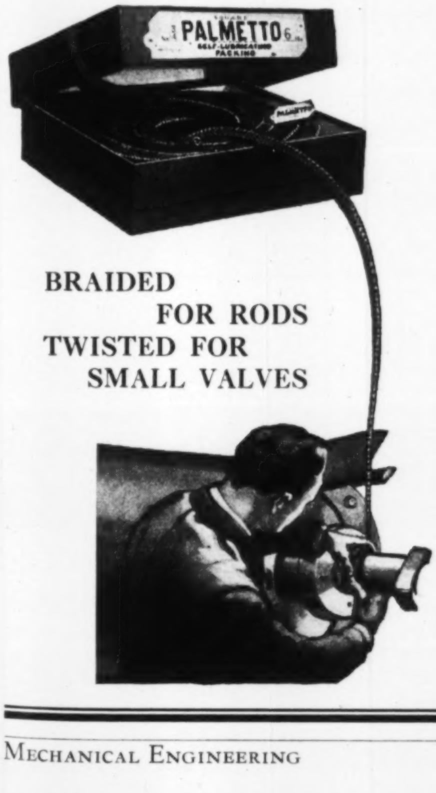
IT COSTS MORE TO REPACK A PUMP THAN THE PRICE OF THE PACKING ITSELF

Experience has shown that the labor charge, the time wasted, the stoppage of production, far outweigh the actual cost of the packing.

If the engineer does it on his own time, he will surely be interested in using a packing that gives long service.

TO SOLVE THIS PROBLEM WE OFFER

For STEAM
(high pressure, superheated)
and
COMPRESSED AIR



BRAIDED
FOR RODS
TWISTED FOR
SMALL VALVES

PALMETTO
REG. TRADE MARK
PACKING

the packing made to withstand high temperatures and so perfectly lubricated as not to harden in service. "Palmetto" gives very long service under these conditions.

SQUARE
PALCO
REG. TRADE MARK
PLAITED PACKING

the packing that keeps the stuffing-boxes tight without friction-producing pressure because of its abundant lubricant. "Palco" does not score the pump shaft, nor so bind as to prevent pump developing full efficiency.

Send for ABC chart of packing services. Also free working sample. State size required and conditions of service.

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CENTRIFUGAL PUMPS
and MINE PUMPS

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